PRODUCT ENGINEERING

VOLUME 7 NUMBER 5

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June Number

Perhaps the term "special" is greatly overworked, but with respect to our June issue, no descriptive term other than "special issue" would fill the bill. What makes it special is a "Where-to-Buy" directory listing manufacturers of electric motors, controls, relays, electronic devices, hydraulic pumps, valves, gages, tubing and similar parts and units. This is a service to our readers that we are rendering in response to repeated requests to furnish such names.

In addition to the "Where-to-Buy" directory of electrical and hydraulic equipment, June *P.E.* will have two feature articles, one on hydraulic operation of machinery, the other on electric drives and controls. These articles will show how engineers in a great diversity of fields have applied electric and hydraulic operation and combinations thereof.

The machines described will include everything from bakery equipment to machine tools, bottling machinery, construction machinery and textile machinery. The controls and devices will include Ward-Leonard controls, various combinations of motor controls, relays, electronic devices, variable displacement hydraulic pumps, solenoid operated valves, magnetic brakes and clutches and innumerable other electric and hydraulic devices.

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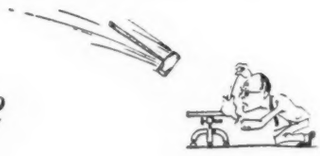
Intimate Correspondence



Electrical Manufacturers Please Note

JUNE *Product Engineering* will contain a directory of Where-to-Buy electric motors, controls, relays, electronic devices and similar electrical equipment. Be sure your name is included by sending us your listing.

This is a reader service. There will be no charge or obligation to the manufacturer. The editors will appreciate your cooperation in making our listing as complete as possible. Please act at once.

Hydraulic Equipment Wanted

IT IS evident that engineers who are developing machines to be operated hydraulically find themselves greatly hampered by not knowing the names of manufacturers of pumps, valves, tubing, oil-resisting high-pressure hose, gages, packings, and the many other items required for hydraulic operation.

As a service to our readers and to relieve us of the job of answering so many letters of inquiry, we will publish a directory of Where-to-Buy hydraulic equipment.

We invite the manufacturers of all such equipment to cooperate with us in making this directory as complete as possible. Tell us what you make in this line. The listing is free. It is an editorial job and will be published in our next number. Please act at once.

An Oversight

PRODUCT ENGINEERING
NEW YORK

I followed closely the series of articles showing the designs of flexible couplings, and I was much pained to note that you had omitted my favorite one, namely the Fast flexible coupling manufactured by Bartlett-Hayward Company of Baltimore, Md. Am I to assume that the author or *Product Engineering* does not put its stamp of approval on this make of coupling? —E.J.M.
St. Louis, Mo.

MENTION in *P.E.* of a machine part or material does not imply that *P.E.* puts on it a "stamp of approval," nor does omission imply the reverse. We are well acquainted with the Fast coupling and so are many of our readers. The coupling has been manufactured for many years, is in wide use and is evidently highly considered by many designers. Its omission was purely an oversight.

An Unlisted Address

PRODUCT ENGINEERING
NEW YORK

In the March number of *Product Engineering* you have an article on page 112 on Polarizing Sheets made by the Land-Wheelright Laboratories. Could you give me their address? —W.J.B.
Toledo, Ohio

MANY others asked the same question. It is a new company, not generally listed in directories, and the address is 168 Dartmouth St., Boston, Mass. It was our error in not having included the address in the article.

Forgings Versus Castings

PRODUCT ENGINEERING
NEW YORK

Have you at any time dealt in *Product Engineering* with the relative merits of castings versus forgings? I have in mind more particularly the precision type of forgings. If you have had such articles I would like to have copies of them. —R.E.W.
Gettysburg, Pa.

WE have to admit a relatively scant amount of space given to the problem of castings versus forgings. And merely comparisons are likely to be odious. But we do wonder if many of our readers would be interested in a comprehensive article on the design possibilities through the use of precision forgings.

Alignment Charts

PRODUCT ENGINEERING
NEW YORK

Unfortunately my subscription to *Product Engineering* started after the first two installments of the series of articles on alignment charts had been printed. Would it be possible for me to get these first installments? Also, will this series appear later in book form? —W.B.
Pittsburgh, Pa.

AT this time we cannot make any definite statement, but it is very likely that the series of articles by Mr. Van Voorhis will be reedited and expanded by the author and appear in book form.

They Make Belleville Springs

IN ANSWER to the item "Springs Wanted" which appeared on this page of the April number, we have been informed that Barnes-Gibson-Raymond, Inc., 6400 Miller Ave., Detroit, Mich. and the Railway Steel Spring Division of the American Locomotive Co., 30 Church St., New York, N. Y., make Belleville springs. Also the Roland P. Place Co., Midland, Mich., "manufacture some sizes, primarily for ball bearing adjustment." Which brings up another question. Why all this interest in Belleville springs? What new applications are possibly being developed?

Are Gear Formulas Used?

PRODUCT ENGINEERING
NEW YORK

I was much interested in the article on gear materials by Sands and Walls that appeared in the October 1935 number. It is undoubtedly of value to all designers of gears. But the other part of the problem is how to calculate the stresses. In this connection I am wondering how many designers use the formulas developed by Earle Buckingham and recommended by the American Gear Manufacturers Association.
—H.A.J.
Providence, R. I.

THE only ones who can set H.A.J.'s wonderings at rest are the gear designers themselves. The recommended practices with reference to dimensional standards are followed by practically all gear manufacturers. But the procedure in making gear calculations is another matter. We would like to get some ideas about this from the designers themselves. One might judge that many of them modify the formulas.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

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Engineering Self Respect

"NO OTHER department has ever dominated the engineering department in this organization, and no other department ever will," declared the head of a big engineering department the other day. He is in a position to make good his statement because he holds one of the highest positions in his company.

The reason he has reached that position is because he has based all of his work on sound fundamental principles, has double-checked it to be sure he was right, and then has stood by his guns. No rule-of-thumb reasoning has been able to shake his position, nor has sales expediency been the deciding factor where it involved a retreat from a sound design.

Don't get the idea that this engineer ignores the contributions that can be made to any design by other departments. Quite the contrary is true. He and his associates make every effort to see that they get the views of the production and sales departments to the end that their design may be possible to make, and possible to sell when made. Conference after conference is held to iron out differences of opinion.

But responsibility for the soundness of a design rests with the engineers. If anything goes wrong they take the blame. If the product is successful they don't hesitate to take credit for their part in it.

In all probability the arrangement just outlined is quite like the situation in most well managed companies. On the other hand there are plenty of places where the engineers dutifully design something that will meet the demands of the market as the sales department sees it—not always too clearly. Or that the production department can make according to its own ideas, which may not be entirely in line with sound engineering practice.

It is to the engineers in the latter kind of company that the almost ideal arrangement of the first paragraph is held up as an example. Obviously they cannot command the respect of the men in other departments if they do not have a healthy measure of respect for themselves, and confidence in their knowledge of engineering fundamentals and in the way in which these fundamentals are being applied. It may be that they have not the aggressive personality of the engineer whose declaration is quoted. That is not essential for there are other ways to accomplish the same object. But any engineer worth his salt must know the principles of design and how to use them. If he sticks to his guns he will surely win out in the end if he is with a company worth working for. If the organization turns a deaf ear to engineering department pleas, he has two alternatives —to reverse this attitude by education, or to find a job where engineering is respected, and thereby maintain his own self-respect.

Drafting Room Methods

Developments that lead to the modern methods of making drawings, notes on handling drawings and drawing records and a discussion of drafting room organization. Part II will appear in July

J. K. OLSEN
Formerly Chief Draftsman, Stewart-Warner Corporation

DRAWINGS of any kind, whether art, mechanical or architectural, are beautiful and pleasing to look at when well done. Examples of masterpieces are the complete drawings of full-rigged sailships, made on parchment paper with a quill, about 200 years ago. The complete ship is shown in every detail, even down to the pulleys. Not only were the old timers artistic "draughtsmen," but they had to know all about the ship building art. And, in addition, it must be considered that they had poor material to work with, long hours and no electric lights.

From this historic example we now consider the first part of this century. By that time the practice of making complete pencil drawings on high-grade, heavy drafting paper and then traced, had already begun. The pencil drawings were made complete to the last detail before being traced. If at any time a change was to be made, the pencil drawing was altered first and then the tracing changed accordingly. Thus two drawings exactly alike were always available. This was convenient in that it permitted changes to be made on the pencil drawing without interfering with the blueprinting of the tracing. This was of greatest disadvantage when extensive experimental changes were being considered, but even that was of doubtful value and one cannot help but think that this custom of duplicate drawings was a waste of money.

Following this period, the methods of making drawings improved rapidly. Instead of the fancy drawings on white paper, the practice changed to making the drawings in pencil directly on tracing cloth and then inking them in. This not only has the advantage of greater economy, but a more accurate drawing is also obtained this way. It is of special advantage when a complicated expensive drawing is made and a strong durable drawing that will not deteriorate is desired. One reason for the preference of tracing cloth is that it will withstand the rough handling in filing and blueprinting.

But the use of tracing cloth was a considerable expense item in the larger concerns. Many of the drawings were large and complicated, and often were duplicates of other drawings except for a few detail changes. For such reasons much thought was given to possible ways of reducing the cost of making inked tracings or finding some other method of making drawings and reproductions. But at that time there was no other available method and complete and accurate drawings were just as necessary in that day as they are at the present time.

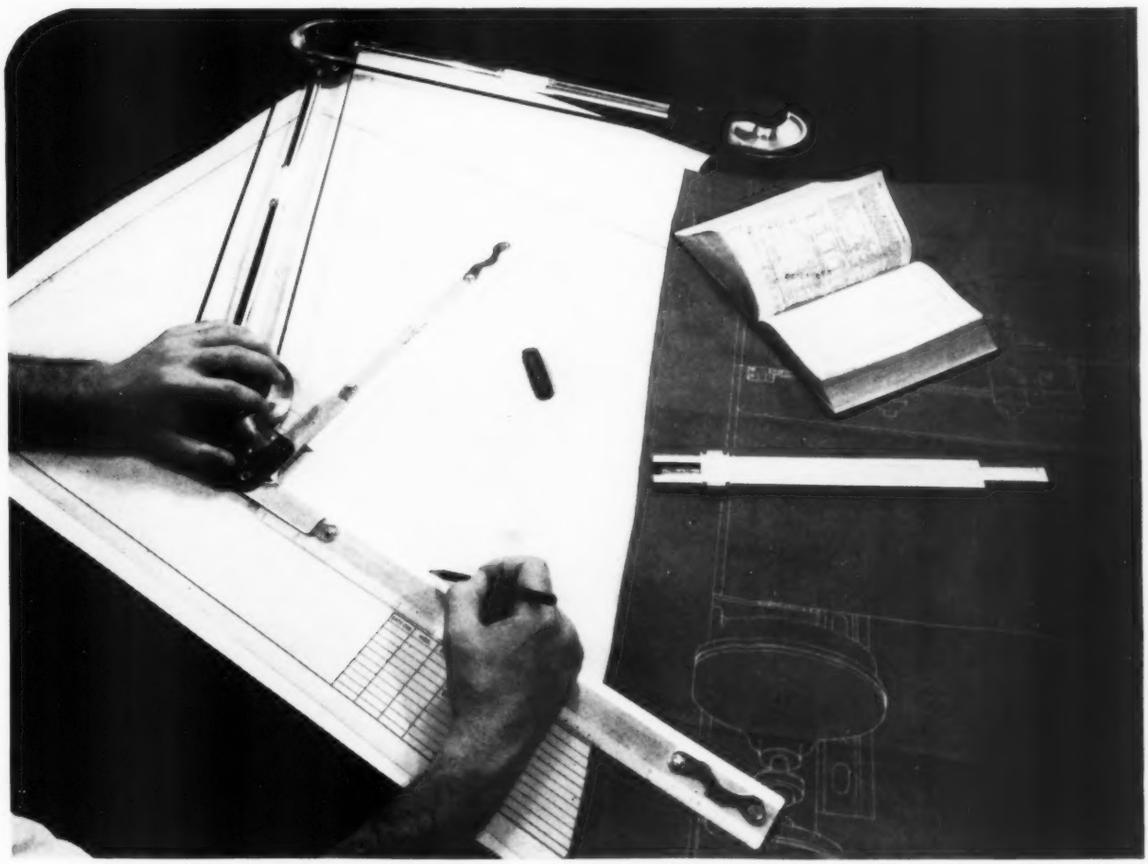
To many manufacturers, the drafting room expense has always looked like so much red ink, and even more so in the last few years. Many means to keep down this expense have been tried and, as everything else upon which effort is concentrated, results have been obtained. Two developments contributed greatly. One of these was the introduction of vellum paper and the other was the many reproduction processes that became available.

The present practice of making design layouts and details directly on vellum paper with pencil seems to be the simplest method obtainable. The pencil drawings on vellum forms can be used directly for production blueprinting. It is surprising how well this works out and one may wonder if there are still further improvements like this to come.

It is interesting to contemplate the reason or steps which lead to the widespread adoption of pencil drawings on vellum paper. Manufacturing plants that were doing extensive experimental work did not wish to go to the expense of making complete drawings for models or test samples of proposed products. Therefore, pencil sketches were usually made on vellum paper. This permitted blueprinting and although the blueprints were often indistinct and not legible, they served their purpose. But as the quality of the vellum paper improved, it was soon noticed that these pencil drawings on vellum were serving the purpose quite well. And because they could be made much more quickly, they came to be used for production drawings when there was a great rush to get the job into the shop. So well did the "rush" drawings serve their purpose that the use of vellum spread quickly.

But it must not be assumed that all drawings should be made on vellum. In making the decision which to use, tracing cloth or vellum paper, it must be considered whether the products being designed are seasonal and also whether the drawings are expected to last for years to come. There are many instances wherein inked tracings on tracing cloth are the most practical solutions. And, then, there will also be with us those concerns or individuals who take a pride in

and Management—I



Modern drafting equipment and instruments leave little to be desired for convenience in making fine drawings

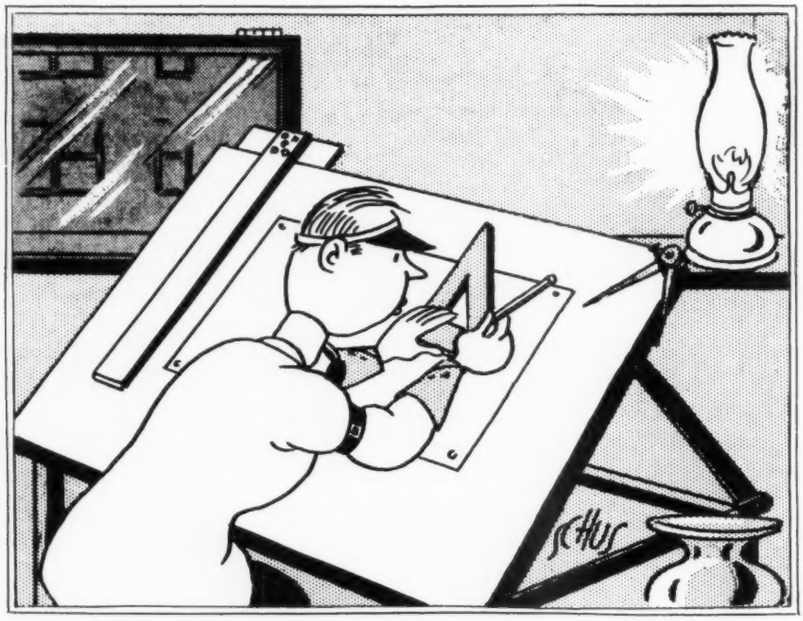
their drawings that impels them to insist that they be neatly inked on tracing cloth so as to be representative of their standard of style. But in addition to the choice between pencil or vellum and inked tracings, there is also to be considered that photographic processes now available make it possible to economically photograph pencil drawings on to opaque or transparent paper or cloth.

In the process of changing from ink drawings on tracing cloth to pencil drawings on vellum paper, there came a change in the technique of making drawings.

Regardless of how a drawing may be made, be it a pencil sketch or an ink tracing, after its completion it should be treated as an important record, the accuracy of which should always be maintained. Not only is the drawing as made originally a record of the efforts of a number of people, but if everything that should go on the drawing is entered properly, the drawing also serves as a medium through which the development of a product can be followed in its chronological development.

In the handling of drawings and drawing records there are two extremes. In the one instance changes in the design made in the shop are not properly recorded on the drawing. The other extreme is that drawings are sometimes cluttered up with shop data such as tools, dies or fixture records. In either instance the results are usually costly. Drawings that do not record all of the dimensions, finishes and arrangements of the products being manufactured are useless by virtue of their untrustworthiness. On the other hand, drawings that are cluttered up with production data soon become such a confused mass of words, sketches and figures that they are difficult to understand and lose in clarity.

In connection with drawing records, it should be emphasized that no changes in the design of a product should be established except by the engineering department, and the authorization from the engineering department to the production department to make the change should always be in the form of a revised blueprint or a blueprint of the revised design. Some form of revision column should be incorporated in the form on which the tracings are made. All changes should be recorded in this column. The record should not only indicate the change that has been made, but also the date should be specified and the initials of the individ-



Old-timers worked under many difficulties yet produced masterpieces of draftsman's art

ual who authorized the change. Also, when the drawing has a "used on" column to show where the part or sub-assembly is used, if the use of that part on a certain product is discontinued the corresponding item should be crossed off by running lines through it. It should not be erased as that would destroy the record. Also, on assembly drawings when items in the bill of material are no longer used, the items should be crossed off.

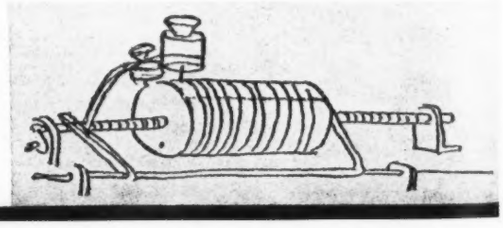
Numerous different forms of revise columns are in use. But in each instance, the information should be complete. Changes in dimensions or tolerances should have recorded the dimension that was changed. If changes are numerous it may be advisable to make a new tracing which supersedes the old tracing, a fact which should be recorded on both tracings.

Drawings properly kept up-to-date not only show the design of the product as it is being manufactured, but also are a chronological record of the history and improvements that have been made in the products. This has proven many times to be one of the best evidences in patent suits. Properly signed and dated drawings are usually accepted by the courts as excellent evidence. In some plants and engineering offices it is also the practice to have the inventor or designer date a new design, both when he starts his layout and again when the layout is finished.

With further reference to the problem of keeping drawings up-to-date, it is true that in some plants the drafting department may be lax in keeping its records straight. On the other hand, sometimes the factory takes away the lead from the engineering department and makes changes in the shop without consulting the engineering department. But such conditions will sooner or later cause trouble. It has been shown repeatedly by experience that it is much more costly to bring drawings up-to-date after the mistakes have been made, than it is to keep the records straight. And, regardless of the reason for laxness and inaccuracies in drawing records, the responsibility is always that of the engineering department. If the management is properly informed, steps will quickly be taken to see to it that the production department respects the drawings of the engineering department.

A striking parable that illustrates the relative value of correct and incorrect drawing records, is the story of a treasure map. As drawn originally any person using the map could readily uncover untold wealth. But someone came along and took away two of the land marks and of course did not note the change on the map because he did not know of its existence. And thus it came about that the man who found the map and organized an expedition to search for the treasure never found it. Similarly, to a greater or lesser extent changes in design that have not been recorded on the drawing have caused great losses. But in the latter case the loss is a direct and inescapable penalty.

Failure to record changes is almost as bad as not making any drawings at all. Perhaps one of the oldest and most striking examples of the importance of drawing records is the failure of Archimedes to make any sketches of the almost innumerable inventions for which he is credited. He left no tangible record as evidence of his accomplishments, and although he is suspected of having developed a great number of things, his engineering feats for which he is credited are largely



Edison's crude sketch of his first phonograph served as a definite record of his accomplishment

legendary. Perhaps if he had left some drawings or other proofs to posterity he would be considered the greatest engineer of all time.

The desire of management to minimize drafting room expenses has already been mentioned. During the past few years much pressure was brought to bear on the drafting room to reduce costs. In some instances, and perhaps too many, drawings were not made because it was thought to save money thereby. One practice was to give the pattern makers or model makers and mechanics half finished drawings for a layout from which to work. It was then left up to the mechanic to "dope out" the missing parts of the drawings. Although this procedure slightly decreased drafting room expense, the result was invariably mistakes and spoiled work that cost much more than the slight saving in the drafting room. The absurdity of such a "penny-wise and pound-foolish" policy becomes more apparent when it

is considered that in most instances, even if no mistakes were made, the extra time taken by the model maker or mechanic would cost several times the amount that would have been paid to a draftsman to do the necessary sketching. But wages paid to mechanics are a production expense while drafting is too frequently classified as overhead; though bookkeeping might indicate a saving, the balance sheet will show the loss, hidden though it be.

Looking at this subject from a broad point of view, it should be evident that the workability of an idea should be determined on paper before any manufacturing expense is involved. It is the most simple way to show both the inside and outside of a product as it actually appears. Drawings will define the exact shape of every part accurately and quickly, show the object correctly, and also its relation to other parts, and the mechanical functioning can be checked readily. On the other hand, verbal instructions and written description are easily misunderstood. When properly executed, drawings serve as an economical error eliminator.

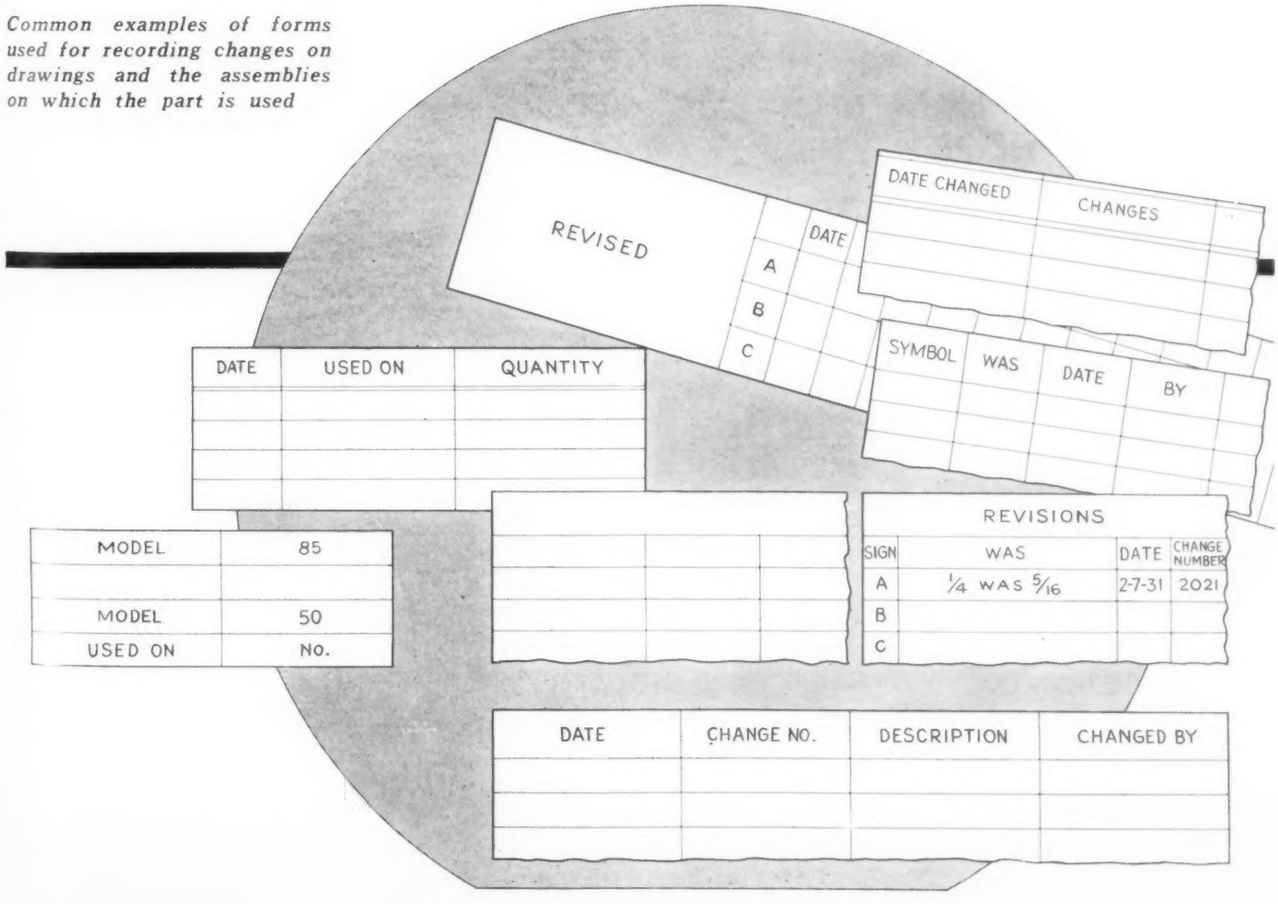
The organization of a drafting department will vary to a considerable extent according to the size of the plant, the kind and number of products to be designed, and also the importance that the management attaches to the work of the department.

Generally in large plants the work is divided among groups or squads with a checker in charge of each separate line of product. For plants with a diversified line of products, this is an efficient and practical system. It gives an organization wherein there are a number of specialized groups.

If the plant is large enough, it is good practice to have at least one assistant to the checker in each group. He should be a man who is well posted and who can, in case of necessity, substitute for the head checker. But in smaller plants there is seldom any specialized organization, usually because there is no need for it. Where there are only a few in the drafting department it becomes a case of "you do that and I do this," and the shop or somebody else takes care of the rest. But if the plant grows, this condition must be corrected.

In the larger organizations it is good practice to shift the draftsmen around so as to give each one a wider experience and also gives the chief draftsman an opportunity to find out their qualifications. In a drafting organization that functions properly, it should be so managed that when a large important rush job is received, the man in charge should be able to swing the whole force on it, regardless of how many different groups there may be. This sometimes causes slight disruption. A squad boss who has some of his men temporarily taken away from him may think that the importance of his work is underestimated. Then there is also the man who thinks that he is such an expert on one kind of work that he should not be transferred, even temporarily. And then there is the man who thinks that he is too good for the kind of rush work that he is called upon to do. In every instance, the temporary reorganization should be carried through, even if some of the men object to it so strongly that they have to be discharged. In a time of rush, delivering blueprints is just as important as making mathematical calculations.

Common examples of forms used for recording changes on drawings and the assemblies on which the part is used



PRODUCT DEVELOPMENTS

• *Die Castings for Strength and Economy*

Growing popularity of home workshops has enlivened competition among manufacturers of such equipment. Prices must be low to attract a broad market. Machines must be adaptable to a wide range of use and sturdy enough to withstand a normal amount of abuse.

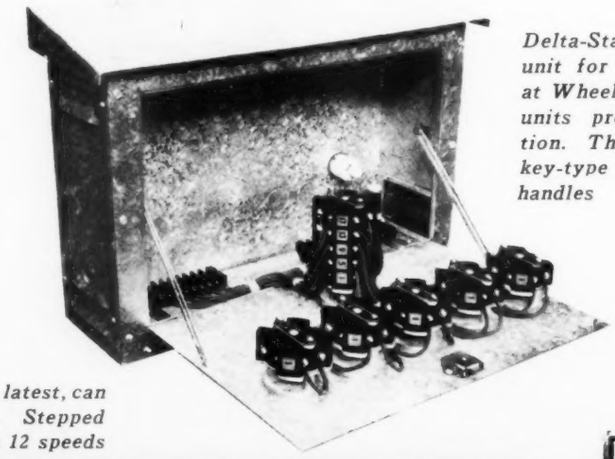
In the latest design of Walker-Turner machine, the nucleus of the equipment is a work bench on which various tools can be mounted. The tools can be purchased as separate units as desired, from which the equipment gets its name "Add-A-Tool."

A ⅓ hp. split phase reversing motor is mounted on a hinged bracket fastened to the rear face of the bench at one corner. The drive is through stepped V-pulleys, first to a countershaft and then to the machine units which include a lathe, band saw, jig saw, jointer, and similar units. The drive to the band saw is through a flexible shaft. A reversing motor is used because some of the units must be run in a direction opposite from the others.

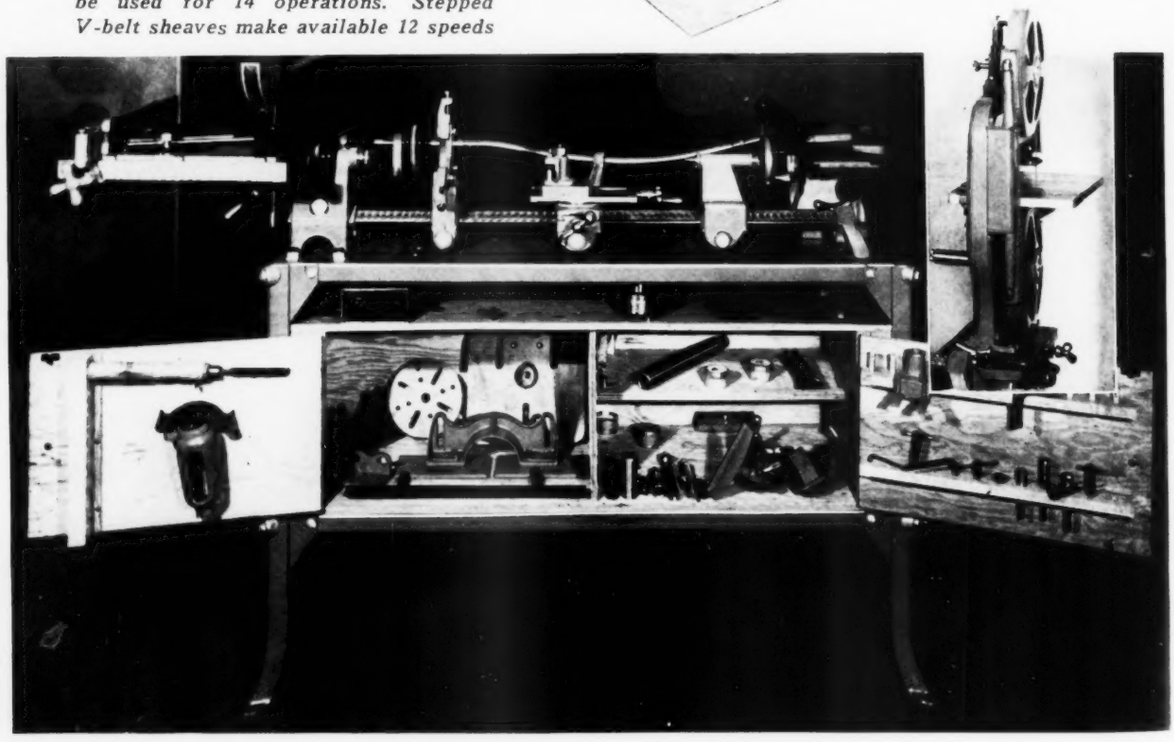
More than 40 parts of the machine are die castings, including the control wheel, head stock and tail stock, wheel guards, V-pulleys, knobs, guides, and similar parts. It is also of interest that ball bearings are used in the head stock, jack shaft and band saw wheel. The planer has bronze bearings.

• *Snap-On Moldings For Color Selection*

In the new line of Dayton refrigerators it has been made possible to offer the unit with a wide selection of colors for the embellishing molding without requiring large inventories of refrigerators. This has been done through the simple device of designing the moldings that embellish the front of the cabinet so that they can be readily



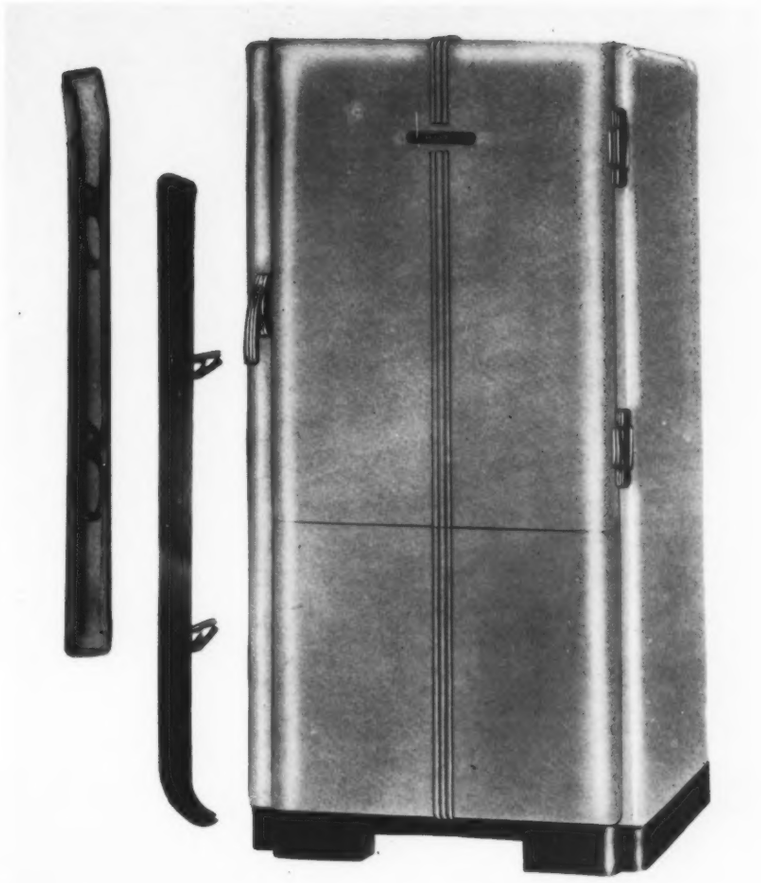
Delta-Star motor control unit for outdoor service at Wheeler Dam. Heater units prevent condensation. The switches have key-type removable handles



Add-A-Tool, Walker-Turner's latest, can be used for 14 operations. Stepped V-belt sheaves make available 12 speeds

snapped on or off to suit the taste.

As shown in accompanying picture the moldings are provided with spring clips similar to those used in attaching automobile upholstery. The moldings are made up in a large variety of colors and are stocked by the dealer at a negligible inventory cost. When the customer has expressed his desire for a certain color to his own individual taste, it is merely necessary to pull off the molding that is on the cabinet and snap-on the molding of the desired color. It is claimed that this is an exclusive feature of the Dayton refrigerator.



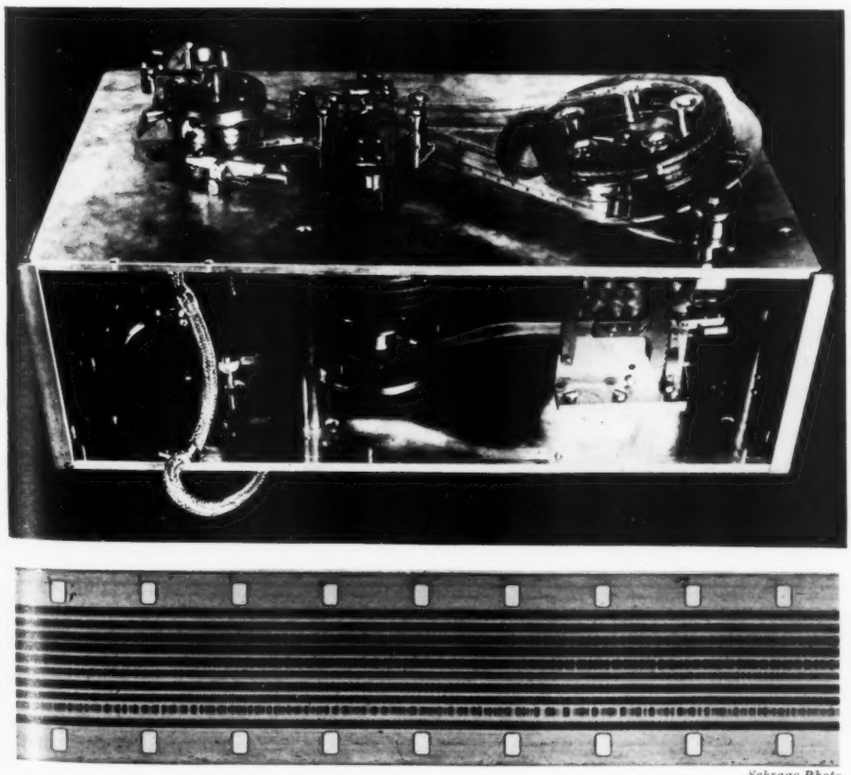
Decorative moldings on Dayton refrigerators, held by spring clips are easily replaceable with moldings of other colors

• *Phonograph Uses Endless Sound Film*

In a recently developed phonograph, a 16 mm. film with 10 sound tracks is wound upon the large drum, called "trick roller," shown at the right in the accompanying illustration. From the drum, the film is lead through small guide rolls to the sound reproducer and then to the counter or idler roller at the left, from where it goes back to the main drum.

The main drum has 5 small rollers around which the film reel is held. As shown in the picture, the film is lead out between two of the rollers, the reel being tilted. Thus the film unrolls from the inside and rolls up on the outside simultaneously. The sound pick-up device consists of a photoelectric cell and a small electric lamp, both contained in the small box in the center of a reproducer.

After one of the 10 sound tracks has been sent through the pick-up device or reproducer, the pick-up "jumps" automatically to take the next sound track. So quickly is this done that no interruption is recognizable by the ear.



Schrage Photo

The Phono Reel and a close-up of the 10-track sound film in the form of an endless ribbon

• *New Stone Grinder With Flexible Drive*

In the new type of grinding machine for use on marble and other stone, manufactured by the Lincoln Iron Works, the reciprocating table is driven by a Sellers spiral gear

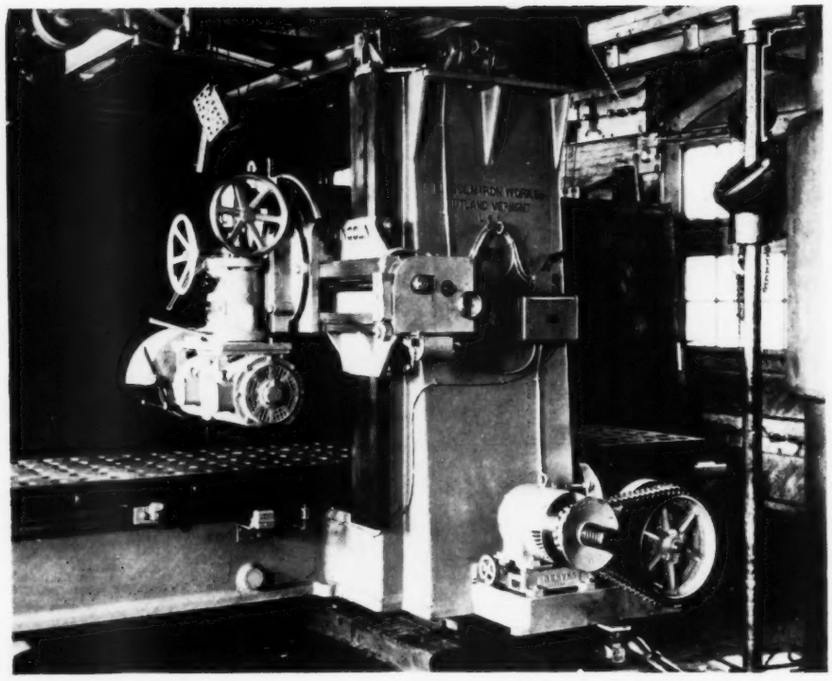
and rack. The table is of double-deck construction, the upper deck having stake dog holes for holding the work and the lower deck of the table being solid. The latter protects the driving mechanism from water and grit.

Variable speed for the table travel is obtained through a Reeves varispeed pulley which is mounted on the shaft of the driving motor, as shown in the picture. Reversal of the table travel is automatic through the use of limit switches and adjustable tripping dogs on the table which reverse the direction of rotation of the driving motor. Push-button operation is also provided.

The grinding wheel is carried on a universal head which may be tilted and locked in any position between horizontal and vertical. This feature makes it possible to use cylindrical wheels for grinding flat bevels. Similarly, when a profile is to be ground the axis of the wheel can be tilted. This makes it possible to use a profile wheel wherein the difference between the largest and smallest grinding diameter is a minimum. This minimizes the amount of wasted wheel when the wheel has been worn away at the smallest diameter. Also the surface speed at all points on the wheel will be as nearly the same as possible, which produces a smoother finish because it enables uniformly high surface speeds. Another factor is that at low speeds the wheels wear away faster and the finish is not uniform. If the grinding wheel is usable down to the diameter of the arbor, the tilted head may add 60 per cent to the wear life.

The grinding wheel motor is 30 hp. A motor-driven cross traverse is provided for the universal head, as well as a motor driven raise and lower for the cross-rail. To allow for close fitting of the grinding wheel, hand adjustment is also provided for both of these movements.

The grinding motor can be swung around at right angles for grinding cross-wise of the table. An automatic index pin and clamping device locks the head in either position for grinding length-wise or cross-wise of the table.



Planer type grinder for stone, built by Lincoln Iron Works. Variable speed pulley, reversing motor, and universal head

Corrugated thin bimetal disk of small mass gives snap action and high sensitivity to the new line of Spencer thermostats

A new sport. Merely swaying the body back and forth propels the new Ingo-bike. The rear axle is eccentric to the wheel

• *New Room Thermostat For High Voltage*

In the accompanying picture is shown one of the new line of room thermostats recently announced by the Spencer Thermostat Company. One of the features of these new thermostats is the concealed contacts which not only provide full protection from all dust, but are also necessary because the thermostat

Lincoln Electric Company

World's largest all-steel press brake, 500-tons capacity, and revolutionary in design in that neither top nor bottom jaw member is stationary

can be used for high voltage service. For this reason, the units are made with a dead front; that is, no live parts are exposed.

The thermostatic element in these units is a bi-metal disk which gives a snap-action. In these new models greater sensitivity is given to the disk by giving complete freedom for air flow through the chamber containing the disk. This has been achieved by removing all unnecessary elements from the disk chamber. Also, the disk being relatively thin, contains a relatively small amount of metal and hence responds quickly to temperature changes. Being corrugated the amount of surface exposed to heat absorption is relatively great and results in more power per unit of mass and per degree of change of temperature.

• *Steel Press Brake Has Two Moving Rams*

In the new all-welded steel press brake manufactured by the Boom Boiler & Welding Company, instead of a ram pressing down on a stationary bed-plate, a top and a bottom ram are pulled together. It is claimed by the manufacturer that this eliminates approximately 30 per cent in material and permits easy adjustment for bending by raising or lowering the bottom leaf. This is done by merely pressing a switch mounted on the front of the machine thereby controlling a motor that, through a worm drive, raises or lowers the bottom leaf.

Another feature of this new type of design is that all driving mechanisms, adjustment shafts and similar parts are below the floor level, leaving the entire top clear and eliminating danger resulting from possible overhead breakage.

The press brake illustrated here is of 500-ton capacity, about 24 ft. long over-all and 6 ft. 9 in. high above the floor. It weighs 61 tons. The links which pull the two leaves together are 8 ft. 3 in. long over-all, 8 in. thick and 3 ft. 4 in. wide.

Construction is entirely of steel, arc welded. Not a single casting is used. According to the manufacturer, this permitted 30 days' saving in time and $2,200 reduction in cost through elimination of patterns and pattern drawings. It is also claimed that $1,500 was saved through the elimination of machining. Much of the weight saving is attributed to the greater rigidity of steel over cast iron. The machine is driven by a 30-hp. motor with a V-belt drive to the 2-ton flywheel gears.

• *Random Jottings About New Developments*

The interior of radio cabinets are now metal-sprayed with zinc in order to shield them.

* * *

In the new air separator made by Motor Improvements Company the filtering element is made of a special alloyed bronze ribbon which is wedge-shaped in cross-section. One of the faces has ridges 0.0005 in. high placed at $\frac{1}{8}$ in. intervals. The ribbon, standing on edge, is closely wound around a cylinder. The result is a smooth-surface hollow cylinder with a series of slots 0.0005 in. wide and approximately $\frac{1}{8}$ in. long, through the wall.

* * *

Because of its strength, stiffness, corrosion resistance and galvanic neutrality with bronze impellers, electric motor shafts for centrifugal pumps for shipboard service are made of Monel metal in a design recently developed by Diehl Manufacturing Company.

In bottle filling machines of the circular rotating type used for filling carbonated beverages, it has been found that when one bottle explodes all the others in the circle will do likewise simultaneously. To overcome this situation the machine is equipped with rubber pads that separate the successive bottles.

* * *

A nickel bronze alloy containing 87.5 per cent copper, 11.0 per cent tin, and 1.5 per cent nickel, is now being produced by the Cramp Brass & Iron Foundry for applications requiring surface hardness and core toughness.

* * *

One manufacturer uses Lignum-Vitae bushings on wrapping machines where they do not want to use oil for fear of damage to the circulars or wrappers.

* * *

In a glass desk made by Libbey-Owens-Ford Company in a variety of colors, both top and base are of flat tempered glass. The desk requires no painting to retain its luster.

How to Specify Springs

R. L. STOUGHTON
Lee Spring Company

OBJECTIVES in spring design are stability, accuracy and endurance. Springs must not set or change dimensions, diameter and structure of wire must be uniform and stresses must be within limitations imposed by the expected number of operations.

Stability requires a design that will safely support the load. When limitation in space restricts the design, materials with high elastic limit must be selected. To determine the margin of safety, the stress should be calculated.

Accuracy requires care in fabrication as well as uniform spring material. For commercial wire, accepted limits in diameter must be recognized. Springs requiring small wire sizes are usually made of music wire with diameter tolerances as follows:

Diameter range, in.	Tolerance, in.
up to 0.016	+0.00025
0.017–0.062	+0.0005
0.063–0.080	+0.0010
0.082–0.104	±0.0010
0.105–0.144	±0.0015
0.145 and up	±0.0020

Hard-drawn and oil-tempered steel wire is not used ordinarily for sizes below $\frac{3}{64}$ in. A tolerance of plus or minus 0.001 in. is accepted for diameters from $\frac{3}{64}$ to $\frac{3}{32}$ in. and 0.002 in. tolerance, plus or minus, for larger sizes. However, closer tolerances are obtainable for a small premium when higher accuracy is needed.

Variations in hardness and tensile strength also introduce inaccuracies in finished springs. Close control over heats is essential to obtain variations less than 5 per cent in tensile strength. Greater variations can be expected in lower cost hard-drawn steel wire.

Inaccuracies in coil diameter and number of coils occur in all types of helical springs, while springs wound with clearance between coils are subject to further variations in length and squareness of end coils. These variations increase in magnitude with larger ratios of coil diameter to wire diameter, as shown in the table, resulting in possible variations in deflection-rate of 10 per cent or more.

Manufacturing Variations of Springs

INDEX D/d	4	8	12
Coil Diameter, In.	Plus or Minus Variations in Diameter in Inches		
$\frac{1}{8}$	0.0020	0.0030	0.0045
$\frac{1}{8}$ to $\frac{3}{16}$	0.0030	0.0045	0.0060
$\frac{3}{16}$ to $\frac{1}{4}$	0.0045	0.0060	0.0080
$\frac{1}{4}$ to $\frac{3}{8}$	0.0060	0.0080	0.0100
$\frac{3}{8}$ to $\frac{1}{2}$	0.0080	0.0100	0.0125
$\frac{1}{2}$ to $\frac{3}{4}$	0.0100	0.0125	0.0150
$\frac{3}{4}$ to 1	0.0125	0.0150	0.0225
1 to $1\frac{1}{2}$	0.0150	0.0225	0.0313
$1\frac{1}{2}$ to 2	0.0225	0.0313	0.0470
2 to 3	0.0470	0.0625	0.0938
3 to 4	0.0625	0.0938	0.1250
4 to 5	0.0937	0.1250	0.1560

INDEX D/d	Length Variations in Plus or Minus Per Inch of Spring		
	4	8	12
5 coils per in.	0.020″	0.030″	0.040″
10 coils per in.	0.030″	0.040″	0.050″
15 coils per in.	0.040″	0.050″	0.060″
20 coils per in.	0.050″	0.060″	0.070″

INDEX D/d	Squareness Variations in Degrees for Ground End Springs		
	4	8	12
5 coils per in.	$1\frac{1}{2}$ to 3 deg.	2 to 4 deg.	$2\frac{1}{2}$ to 5 deg.
10 coils per in.	2 to 4 deg.	$2\frac{1}{2}$ to 5 deg.	3 to 6 deg.
15 coils per in.	$2\frac{1}{2}$ to 5 deg.	3 to 6 deg.	$3\frac{1}{2}$ to 7 deg.
20 coils per in.	3 to 6 deg.	$3\frac{1}{2}$ to 7 deg.	4 to 8 deg.

Coil Variations in Plus or Minus

4 coils to less—$\frac{1}{4}$ coil
4 or 8 coils—$\frac{1}{2}$ coil
8 to 15 coils—$\frac{3}{4}$ coil
15 to 25 coils—1 coil

These expected variations can be reduced by greater care in manufacturing, and a 100 per cent inspection will eliminate all springs outside of the required limits. However, slower production speeds and added operations for higher accuracy increase manufacturing cost.

Assuming that requirements for stability and accuracy are met, the endurance or life depends on the material selected, its corrosion resistance, the finish used, and the working stresses. Steel springs can be protected from corrosion by an oil dip for mild service or by enamel or plated finishes. These coatings, however, may not penetrate between the coils of close-wound springs. Either the wire must be plated before coiling, or a corrosion-resistant metal must be used.

Heat also affects the life. Not only will the spring-rate vary with the temperature, but the strength of the material decreases with increased temperature. Plain carbon steels are sensitive to temperature; somewhat greater resistance is offered by chrome-vanadium alloys. Stainless steel offers good resistance, but the best materials for high temperature service are tungsten and nickel-chrome alloys.

High speed, period of natural frequency, stress range and wire imperfections also are important factors affecting service life or endurance, but most applications are of such special nature that no general rules can be given.

To properly evaluate the factors of stability, accuracy and endurance in any spring design requires more information than is usually supplied by the designer. As a guide to the design data needed, the accompanying "Spring Specification Form" has been developed as the result of several years experience in setting up spring requirements. The numbered items are arranged in the order in which they are usually obtained in calculations, and include sufficient information to completely specify all ordinary types of springs.

GENERAL SPRING SPECIFICATION FORM

Part Name or No. _____ Blue Print No. _____

	SUBJECT	SPECIFICATION	PLUS	MINUS	REFERENCE
1	Type of Spring				COMPRESSION–TORSION–FLAT
2	Kind and Grade of Metal				EXTENSION–WIRE FORM
3	Size of Material				SPECIFY BY NAME AND S.A.E. NO. OR COMMERCIAL DESIGNATION OF GRADE.
4	Outside Diameter of Spring				SEE WIRE DRAWING LIMITS
	Works Inside Size Hole — or — Inside Diameter of Spring				SEE PLUS OR MINUS LIMITS
					SPECIFY IF CLOSE FIT
	Works Over Size Rod				SEE PLUS OR MINUS LIMITS
5	Free Length				SPECIFY IF CLOSE FIT
6	Solid Length				SEE PLUS OR MINUS LIMITS
7	Load				TOTAL ACTIVE COILS PLUS THREE COILS MAXIMUM IF ENDS ARE SQUARED OR CLOSED AND TWO IF ENDS ARE SQUARED AND GROUND.
	At Deflected Position of				SEE PLUS OR MINUS LIMITS
8	Initial Tension				COMPRESSED LENGTH FOR COMPRESSION EXTENDED " " EXTENSION DEGREE SEPARATION OF ENDS FOR TORSION
9	Number of Coils				INITIAL TENSION-EXTENSION SPRINGS WOUND TIGHT NO " " " " LOOSE
10	Direction of Coils				SPECIFY INITIAL TENSION IN LBS. IF IMPORTANT.
11	Pitch of Coils				COMPRESSION SPRINGS REQUIRE 1.5 TO 2 DEAD END COILS WHEN THE ENDS ARE SQUARED AND GROUND.
12	Space Between Coils				RIGHT OR LEFT HAND. LEFT HAND WILL BE INFERRED IF NOT SPECIFIED.
13	Ends				WHEN NUMBER OF COILS ARE NOT GIVEN
14	Finish				WHEN NUMBER OF COILS OR PITCH ARE NOT GIVEN
15	Remarks:				IF GROUND SPECIFY DEGREE OF SQUARE WITH AXIS–SEE PLUS OR MINUS LIMITS
					PLAIN–JAPAN–CADMIUM PLATE–NICKEL PLATE CHROMIUM PLATE–COPPER PLATE–TIN–GALVANIZE

Sketch Special Shapes or any Special Style of Ends not given Descriptively

VIEW VIEW VIEW

For ordinary springs, the use of this form will give the manufacturer enough information

Stress Calculations for Thin Aluminum Alloy Sections

S. A. KILPATRICK, *Test Engineer,* and O. J. SCHAEFER, *Stress Analyst*
The Glenn L. Martin Company

A discussion of the resistance of box or tubular sections subjected to torsion, including equations for calculating the stresses and deflections, and how to apply them

PART IV—Torsion

ALTHOUGH any type of section has a certain amount of resistance to torsion, the closed section is by far the most efficient from the standpoint of torsional rigidity and weight. For this reason, in modern aircraft structures the closed section is employed for all the main structural parts such as wings and fuselage. The resistance of such box and tubular sections subjected to torsion will be discussed.

The subject of torsion is quite complex, but by the aid of the well-known membrane analogy, first introduced by L. Prandtl, many simple solutions have been developed. For the single cell thin-walled box as shown in Fig 2, and for such sections as tubing, the equations for stress and torsional deflection are as follows:

$$f_s = \frac{T}{2At} \tag{1}$$

in which f_s = shearing stress in lb. per sq.in.
T = applied torsional moment in in. lb.
A = inclosed area of box in sq.in.
t = thickness of the portion of skin or covering being investigated.

$$\theta = \frac{T}{4A^2G}\int\frac{ds}{t} = \frac{T}{GJ} \tag{2}$$

in which θ = angular deflection in radians per inch of length
G = torsional modulus of elasticity or modulus of rigidity generally taken as $0.4E$ for aluminum alloy.
ds = differential element of perimeter.
J_s = torsion constant of the section.

For the section shown in Fig. 2 we have:

$$\int\frac{ds}{t} = \frac{s_1}{t_1} + \frac{s_3}{t_2} + \frac{s_2}{t_3} + \frac{s_2}{t_4}$$

Although we have been mainly concerned with the calculation of stresses and the determination of allowable stresses, there is a point concerning torsional deflections to which attention should be called. When the sides of the box are designed as tension field members the equation for torsional deflection θ, is not directly applicable owing to the fact that the shearing deflections of such a member is increased.

Paul Kuhn has shown (Reference 1, end of text) that the same general form of the equation can be used if a reduced thickness of the side is substituted for the actual value. Two reductions appear to be necessary. The theoretical shearing deflection of a tension field web is 1.6 times as great as that of a shear resistant panel, assuming the modulus of rigidity to be 0.4 times the modulus of elasticity. The first reduction would therefore make the effective thickness, t_e, equal to $\frac{5}{8}t$. The above relations, however, assume infinite rigidity of the beam flanges. Also, a further reduction of the effective thickness would be necessary to account for stress concentrations in the web. This is because the diagonal tension stresses tend to increase at the stiffener connections and decrease between stiffeners.

A chart for the efficiency of the sheet for various ratios of stiffener spacing to depth and for various values of stress in the sheet is given in Reference 1. In a properly designed tension field panel the deflection can be obtained with reasonable accuracy using only $t_e = \frac{5}{8}t$ providing the stresses are relatively low.

The foregoing equations for the determination of torsional stresses are only strictly true when the torsional moment is applied ideally around the perimeter of the section. This, of course, is never the way it actually is. It is therefore necessary to place ribs or bulkheads at all points of application of load, designed in such a

Fig. 1—After part of hull of Martin Model 130, Pan-American Clipper. Note the two rear bulkheads which are designed to transmit fin loads to hull and distribute torsion to box

Fig. 2—Single cell thin-walled box section, for which the equations for stress and torsional deflection are given in the text. Fig. 3—Section of a typical modern box wing which has two cells that effectively resist torsion

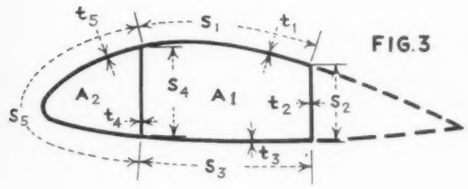


FIG.3

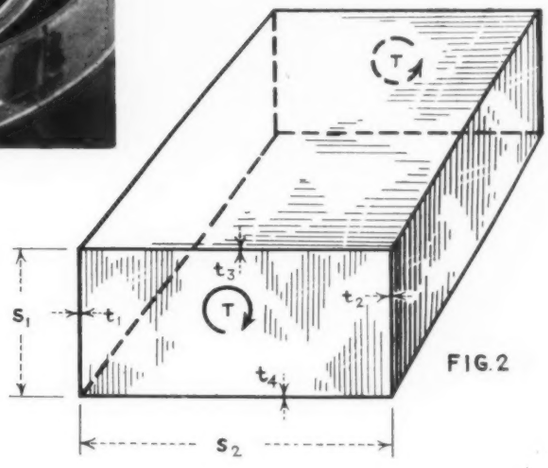


FIG.2

way as to be capable of transferring the external loads directly to the walls of the box.

For fuselage or hull sections and for tubing the foregoing equations will suffice, but for a wing or similar structure of more than one cell, such as shown in Fig. 3 which is a typical section of a modern box wing, it is often desired to know the shearing distribution. The stresses and deflections can be calculated by modifying and altering the equations developed by S. Timoshenko (Reference 2, end of article) to make them more general.

In Fig. 3 it will be noted that the thickness of the various sides of the box are designated as t_1, t_2, etc. The most general case is where even these portions are of varying thickness and the equations shown are therefore general. If we use the specific example of Fig. 3, however, the terms of the equations will be more readily understood. The trailing edge portion or the third cell has been neglected for two reasons. First, this portion resists only a small part of the torque. Secondly, it would greatly complicate the problem to consider more than two cells because the equations become cumbersome. This general case is covered by Paul Kuhn (Reference 3). The equation for the total applied torque is given by:

$$T = 2(A_1h_1 + A_2h_2) \tag{3}$$

in which T = applied torsional moment in in. lb.
A_1 = inclosed area bounded by the two spars and the top and bottom skin, in sq.in.
A_2 = area bounded by leading edge covering and front spar, in sq.in.
h_1 = shear force in lb. per in. run of the perimeter bounding area A_1 but not including front spar web
h_2 = shear force in lb. per in. run of the perimeter which bounds area A_2 but not including front spar web

It should be noted that the shear per in. for the front spar web is given by,

$$h_3 = h_1 - h_2$$

The shear per in. of the three sides of thickness t_1, t_2 and t_3 in Fig. 3 can be obtained from,

$$h_1 = \frac{T}{2} \frac{[b_3(A_1 + A_2) + A_1b_2]}{[b_3(A_1 + A_2)^2 + A^2_2b_1 + A^2_1b_2]}$$

$$= \frac{T}{2K}\left[b_3(A_1 + A_2) + A_1b_2\right] \tag{4}$$

In this equation, over the portion of perimeter marked s_4,

$$b_3 = \int \frac{ds}{t},$$

$$= \frac{s_4}{t_4}$$

Over portion of perimeter marked s_1, s_2, s_3

$$b_1 = \int \frac{ds}{t} = \frac{s_1}{t_1} + \frac{s_2}{t_2} + \frac{s_3}{t_3}$$

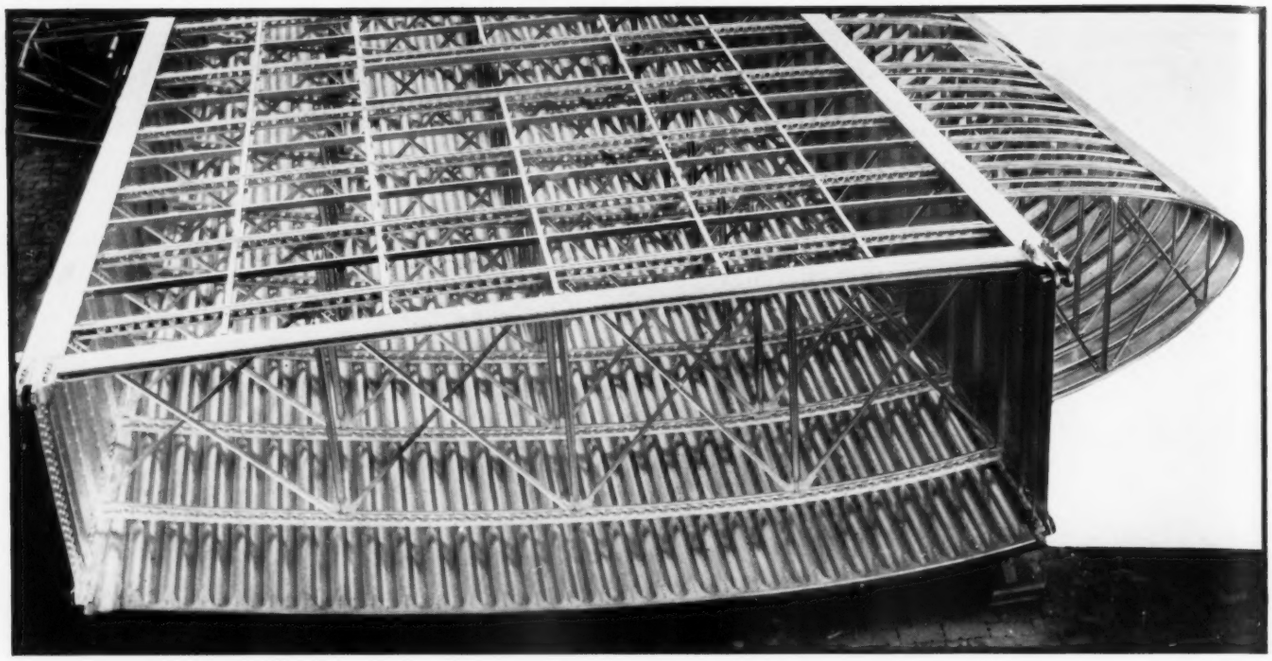


Fig. 4—Box type wing of a Martin Model 130, Pan-American Clipper ship, shown inverted before assembly of bottom skin

Over leading edge part of perimeter marked s_5

$$b_2 = \int_{s_5} \frac{ds}{t} = \frac{s_5}{t_5}$$

The shear per in. for the leading edge covering is given by:

$$h_2 = \frac{T}{2K}\left[b_3(A_1 + A_2) + A_2 b_1\right] \tag{5}$$

In the front spar web the shear per in. is simply,

$$h_3 = h_1 - h_2 = \frac{T}{2K}(A_1 b_2 - A_2 b_1) \tag{6}$$

The shearing stress f_s in any part of the box can be found by dividing the shear per in. by the thickness over the part in question or,

$$f_s = \frac{h}{t} \tag{7}$$

When any of the sides buckle to form diagonal tension fields the tensile stress on these portions, assuming the wrinkles make an angle of 45 deg., is determined as follows:

$$S_T = \frac{2h}{t} \tag{7a}$$

The unit torsional deflection, θ, in radians per inch of length is computed from the equation,

$$\theta = \frac{T}{4GK}(b_1 b_2 + b_2 b_3 + b_3 b_1) = \frac{T}{GJ} \tag{8}$$

In the above expression the factor J is the torsion constant of the section which corresponds to the moment of inertia, I, as commonly used in the standard formulas for beams under flexure.

The equation for deflection, θ, and for the shear loads per in. are strictly true only for panels which are shear resisting. If any of the sides buckle to form diagonal tension fields an effective thickness, $t_e = \frac{5}{8}t$ should again be used in the line integrals, b_1 b_2 and b_3, for the parts that are so designed. It can be seen that here this substitution will affect the shear distribution between the two boxes as well as the deflection, while in the case of a single cell box only the deflections are altered. For the calculation of stresses by Equations (7) and (7a) the actual thickness is always used.

It should be noted, however, that if the allowable buckling stress of the tension field sides is high in comparison to the actual stress the use of an effective thickness, t_e, will not be true. Here, assuming one panel to buckle, to secure a reasonable degree of accuracy it would be necessary to break the applied load up into two parts, one before buckling occurs and the second after it has occurred. For instance, if the torsional moment causing buckling of the side is equal to 50,000 in. lb., and the total applied torsional moment is 120,000 in. lb. it becomes necessary to first calculate all stresses and the deflection under a load of 50,000 in. lb. and then add to these the stresses and deflections under a load of 70,000 in. lb. With the 70,000 in. lb. increment the panel would be handled as a tension field. It can be seen that this procedure would become laborious if all tension field sides buckled under different loads.

Normally, in a wing structure the front and rear beam webs, when designed as tension fields, have buckling allowables so low that they may be considered equal to zero. The top and bottom covering, however, are subjected to axial stresses caused by flexure such that the side stressed in axial tension may have an appreciable allowable buckling stress under a subsequent application of shear. When a member is to remain free

from buckling throughout the major part of the loading it will greatly simplify matters to use the actual thickness of the member in the equations for the total loading. No specific recommendations can be made here without knowing all the details of the particular structure and its loading but the above remarks will be of some value in assisting the judgment of the designer.

In some designs such as the one shown in Fig. 5 the front and rear spars are made to resist all of the bending while the box is assumed to resist all torsional moments. If the bending moment is so divided between spars that the deflections, or more precisely the M/EI curves, are equal at all points, there can be no twist and consequently no torsion. To accomplish this, the portion of the total bending moment resisted by each spar is proportional to the ratio of the moments of inertia of the respective spars to the total moment of inertia, or

$$M_{F1} = \frac{ME_FI_F}{E_FI_F + E_RI_R}$$

and

$$M_{R1} = \frac{ME_RI_R}{E_FI_F + E_RI_R} \qquad (9)$$

in which

M_{F1} and M_R = bending moments in front and rear spars
I_F and I_R = moments of inertia of front and rear spars
E_F and E_R = modulus of elasticity of the spars
M = total applied bending moment

As is evident, for spars of similar material the modulus of elasticity drops out of these equations. The center of resistance to bending is therefore located at the centroid of the moments of inertia. In Fig. 5, this point is designated as $E.A.$ and its horizontal location is simply,

$$a = \frac{I_Rb}{I_F + I_R} \qquad (10)$$

The point thus defined is known as the elastic center of the section and the locus of these points is known as the elastic axis. When an external load is applied along any but this line a torsional moment is produced which is equal to the load times its distance from the elastic axis. This moment is generally considered to be resisted entirely by the box in torsion, an assumption which is quite close to the truth in a normal box wing except near the root. The reason for this is thoroughly covered in Reference 4 by Paul Kuhn. A brief outline is given here with recommendations for approximating the variations without making the calculations too laborious.

If we consider two spars acting in bending which are interconnected by only pin ended ribs any load applied on the ribs will be distributed to the spars in the inverse ratio of its distance from the respective spars. Thus, if a load is applied as shown in Fig. 5 the loads in the spars are:

$$P_{F2} = P(b - c)/b; \quad P_{R2} = P\,c/b$$
$$M_{F2} = P_{F2}L \quad ; \quad M_{R2} = P_{R2}L \text{ (Root moments)}$$

This same proportioning holds if the ribs are rigidly connected providing the spars offer only small resistance to torsion. In the latter case of rigid interconnection, however, if the spars have a high torsional rigidity or if a box is formed as in Fig. 5, the distribution approaches that given by Equation (9). If all torsion about $E.A.$ is resisted by the box in torsional shear there is complete "interaction" between spars and, conversely, if no torsion is resisted by the box the "interaction" is zero. The amount of interaction is dependent upon the ratio,

$$C_i = B_sL^2/A_ib^2$$

In this relation, considering a box of uniform cross-section over the length L, B_s is the total torsional stiffness of the two spars plus that of the box. Since we are considering only a box where the two spars have relatively little resistance to torsion the factor B_s is simply equal to GJ for the box, which terms are as defined previously. The factor A_i is given by $I_F\,I_R/(I_F + I_R)$ when E is constant for both spars. The ratio C_i for a stressed skin box would generally be such that for all points along the span except at the root the moment would divide in accordance with Equation (9). The difference between the moments obtained by the two methods may be written,

$$Me_F = M_{F2} - M_{F1}$$
$$Me_R = M_{R2} - M_{R1}$$

Then, for any degree of interaction between spars the final bending moment in each spar is,

$$M_F = M_{F2} - C_RMe_F = M_{F2} - C_R(M_{F2} - M_{F1}) \qquad (11)$$

$$M_R = M_{R2} - C_RMe_R = M_{R2} - C_R(M_{R2} - M_{R1}) \qquad (11a)$$

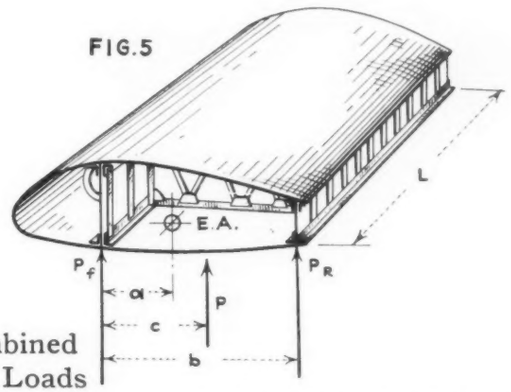


Fig. 5—In this design the front and rear spars are designed to resist all the bending while the box is assumed to resist all the torsion

Stresses for Combined Axial and Shear Loads

The allowable stresses are obtained from the equation

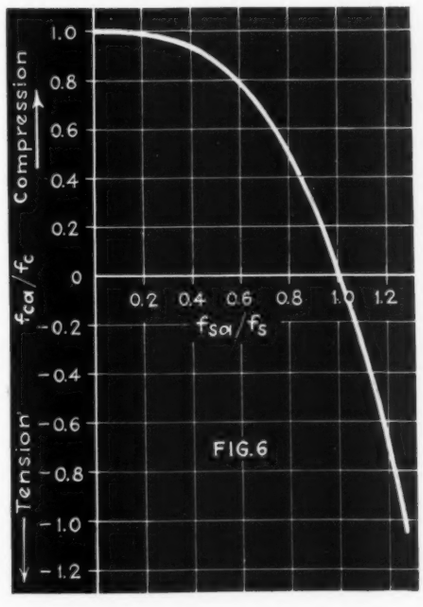
$$1 - (f_{ca}/f_c) = (f_{sa}/f_s)^3$$

Where, f_c = Allowable compressive stress with no shear acting

f_s = Allowable shear stress with no axial load acting

f_{ca} = Allowable compressive stress when a shear stress of f_{sa} is present

f_{sa} = Allowable shear stress when an axial stress of f_{ca} is present



From Reference 4 a good average value for the relief coefficient, C_R, at the wing root for a trapezoidal loading and a box wing appears to be about 0.70. Using this value the bending moments at the root become

$$M_F = 0.7\ M_{F1} + 0.3\ M_{F2} \tag{12}$$

$$M_R = 0.7\ M_{R1} + 0.3\ M_{R2} \tag{12a}$$

Assuming further that C_R increases linearly from 0.7 at the root to 1.0 at 20 per cent of the half-span of the wing, a reasonable approximation of all moments will be obtained. This simply means that Equation (9) may be applied from the tip to 80 per cent of the way inboard and from this point inward Equation (11) will apply, with C_R varying from 1.0 at the 80 per cent distance to 0.7 at the root.

It can be seen, therefore, that the torsional moments being carried by the box will be somewhat reduced near the root. For torsion, however, it will be conservative to assume that the box alone is acting.

In all of the foregoing equations the stresses calculated from torsion are of course pure shearing stresses. This condition will rarely exist in practice, so that some method must be adopted for obtaining the allowable stresses for combined loading. Various methods have been proposed and used, but one of the simplest seems to be the one used by F. J. Bridget (Reference 5). The experiments described in that reference were made on steel and brass tubing with ratios of diameter to wall thickness, D/t, ranging from 470 to 1,800. Various ratios of direct compressive stress to torsional shearing stress were applied, and the results were plotted as shown in Fig. 6. The values f_c and f_s are the allowable stresses in pure compression and pure torsional shear, respectively. The value f_{ca} is the allowable direct compressive stress when the tube is subjected to an initial shearing stress f_{sa}, or vice versa. The curve plotted is a parabola with the equation,

$$1 - (f_{ca}/f_c) = (f_{sa}/f_s)^n \tag{13}$$

The value for n recommended by Bridget is $n = 3$. This method of plotting may be used quite generally for any combination of shear and compression whether for curved sheet or flat sheet and may be used for combined bending and torsion. One series of independent tests on 4-in. O.D. $\times$ 0.035-in. wall, 17ST aluminum alloy tubing ($D/t = 114$) gave a value of $n = 2.9$ for combined bending and torsion.

The equation is also applicable when the axial stress is tension. For instance, if the allowable pure compression load for a tube is —500 lb. and the actual direct load is a tension of +600 lb., the value of f_{ca}/f_c would be (+600/—500) or —1.2. We note that the value of f_{sa} would then be larger than the pure shear stress allowable. This conclusion was reached by Bridget in one series of tests and, although no general rule can be stated as to how far the equation will extend into the tensile range, one thing was worthy of note from that series. The maximum principle stress at which Equation (13) broke down was only about 70 per cent of the proportional limit of the material. This principle stress can, of course, be calculated from equations given in any standard textbook on the strength of materials. It is naturally not to be expected that the equation would be true in any place where the maximum principle stress exceeded the proportional limit in tension or compression or where the maximum shearing stress exceeds the shearing limit of proportionality.

To apply Equation (13) to box sections, such as analyzed in the first part of this article, it is only necessary to calculate, or determine by test, the allowable stresses for direct compression f_c, and the allowable pure shearing stress, f_s. The equation for the allowable shear stress for both curved and flat sheet is given in the March number of *Product Engineering*. The allowable load for curved or flat sheet in direct compression can be calculated from the data given in the April number. Knowing the above values it is only necessary to use Fig. 6 to determine the allowable stresses for any combination of shear and axial stress.

This concludes the series of four articles on "Stress Calculations for Thin Aluminum Alloy Sections" which began in February and appeared in consecutive issues.

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(2) Theory of Elasticity, by S. Timoshenko, McGraw-Hill Book Co., 1934.

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(4) Analysis of 2-Spar Cantilever Wings with Special Reference to Torsion and Load Transference, by Paul Kuhn, N.A.C.A. Technical Report No. 508, 1935.

(5) Some New Experiments on Buckling of Thin-Wall Construction, by F. J. Bridget, C. C. Jerome, and A. B. Vosseller, Transactions A.S.M.E., APM-56-5, Aug. 1934.

(6) Strength Tests on Thin-Walled Duralumin Cylinders in Torsion, by E. E. Lundquist, N.A.C.A. Technical Note No. 427, Aug., 1932.

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ELECTRIC AND HYDRAULIC DRIVES AND CONTROLS

During the past years much progress has been made in the application of electric and hydraulic devices for automatic operation. Magnetic brakes and clutches, solenoids, limit switches, motor controls and electronic devices are being used in many new ways. Hydraulic operation, often in conjunction with electric controls is spreading rapidly into new fields. June *P.E.* will feature these latest developments. Pictures and diagrams will illustrate and explain typical applications.

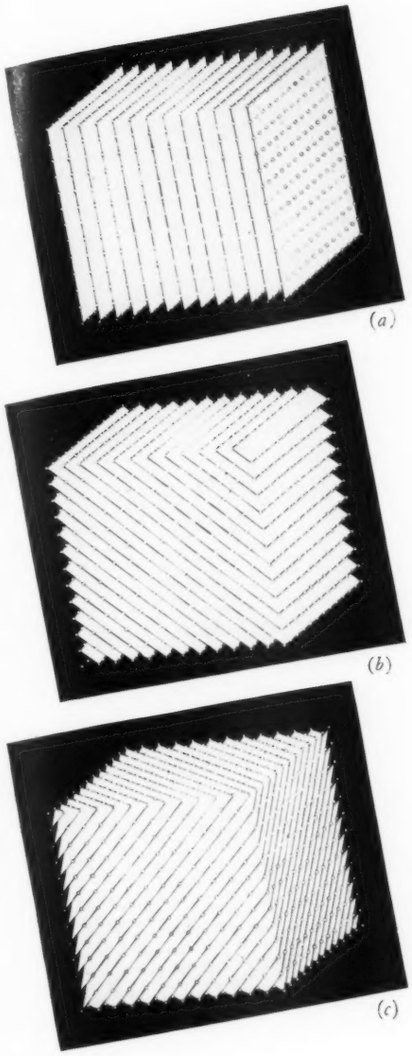


Fig. 1—Three families of planes that reflect X-rays in a crystal with atoms arranged in a cubic pattern. (a) Family or plane parallel to cube face, known as 100 planes. (b) Family of planes through opposite face diagonals, known as 110 planes. (c) Family of planes through adjacent face diagonals, known as 111 planes

Analysis of Materials By the X-Ray Diffraction Method

HERBERT R. ISENBURGER
St. John X-Ray Service, Inc.

Methods and equipment used to identify composition, to measure grain size, to determine the effect of cold work and heat-treatment, and to measure internal strains in materials

AS DISTINGUISHED from radiographic inspection of the interior condition of materials X-ray diffraction analysis is the study of the arrangement of the atoms in materials. Diffraction analysis supplies information concerning the atomic arrangement, the size of the particles, their shape and the manner in which they are arranged within the mass. Diffraction studies also disclose the changes that take place as the result of thermal, mechanical or chemical treatment. In addition, X-rays show the similarity, identity or difference of two materials, and any other characteristics depending upon atomic arrangement.

X-Ray diffraction analysis is based upon a series of discoveries beginning with Roentgen's work in 1895. In 1912 von Laue suggested that if X-rays are similar to light waves their wave-lengths must be of the same order of magnitude as the small distance between neighboring atoms in a crystal, that is, about one hundred millionth of an inch. Therefore, metals should diffract X-rays, giving an effect similar to that produced when a distant light is viewed through a wire screen or an umbrella cover. A symmetrical pattern of spots is seen. The character of the pattern depends upon the nature of the light or the relative position of the light, the cloth and the eye. When these positions are changed, or the cloth is distorted, or cloth of different weave is substituted, the light pattern changes. This pattern is caused by diffraction, or "co-ordinated scattering" of the light-waves passing through the orderly array of openings in the cloth.

A much simpler pattern is observed when a diffraction grating—a series of parallel lines ruled on a transparent surfaces—is substituted for the cloth. A more complicated pattern would be produced by a series of screens at equal distances. The ordinary diffraction grating is one-dimensional, the cloth two-dimensional, the series of screens three-dimensional.

Laue predicted that if the atoms in a crystal are arranged in an orderly manner they should constitute a three-dimensional grating for X-rays and that consequently a diffraction pattern should be produced when X-rays travel through a crystal. This was promptly confirmed experimentally, demonstrating the orderly arrangement of atoms in the crystal, the identity of X-rays and light-waves, and the similarity of size between interatomic distances and X-ray wave-lengths.

As the atoms in a crystal are arranged in an orderly manner, numerous families of parallel planes can be passed through the atom-centers so that every atom-center lies in some plane of each family. Three such families of planes in a simple cubic crystal are shown in Fig. 1. Each family acts as a unit in causing diffraction so that each spot on the X-ray pattern represents diffraction from a particular family of planes. These

characteristic arrangements of atoms are called space lattices. The relative positions of the spots are determined solely by the angles between the incident beam of X-rays and the line normal to each family of planes.

The Laue experiment, while supplying the foundation of X-ray diffraction analysis, gave no information as to the actual magnitude of the X-ray wave lengths or the interatomic distances. This was accomplished by W. H. and W. L. Bragg in 1913. By rotating the crystal during exposure to X-rays, they found that for any position of the crystal the intensity was a maximum when the diffracted beam made the same angle with the surface as the primary beam, and that marked peaks occurred at certain settings of the crystal. In other words, the X-rays behaved as if selective reflection were taking place.

From their measurements the law of X-ray diffraction known as Bragg's Law was deduced. When two trains of waves travel from a source to a point of observation over different paths, they nullify each other unless they arrive in phase. They will arrive in phase only if their paths are equal or differ by a whole number n of wave length λ. Hence, when a train of X-rays is incident at an angle θ upon a family of parallel atom planes a distance of D apart, as shown in Fig. 3, a series of trains will be scattered or diffracted from each plane. These trains will be in phase and reinforce each other most completely when the difference between the paths $2\ D\ sin\ \theta$, between trains from successive planes is equal to $n\ \lambda$, a whole number of wave lengths.

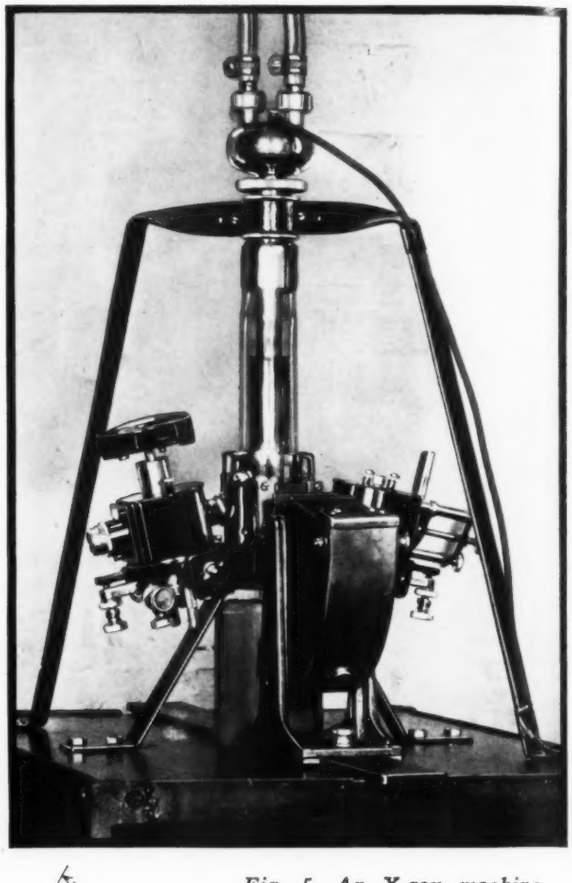
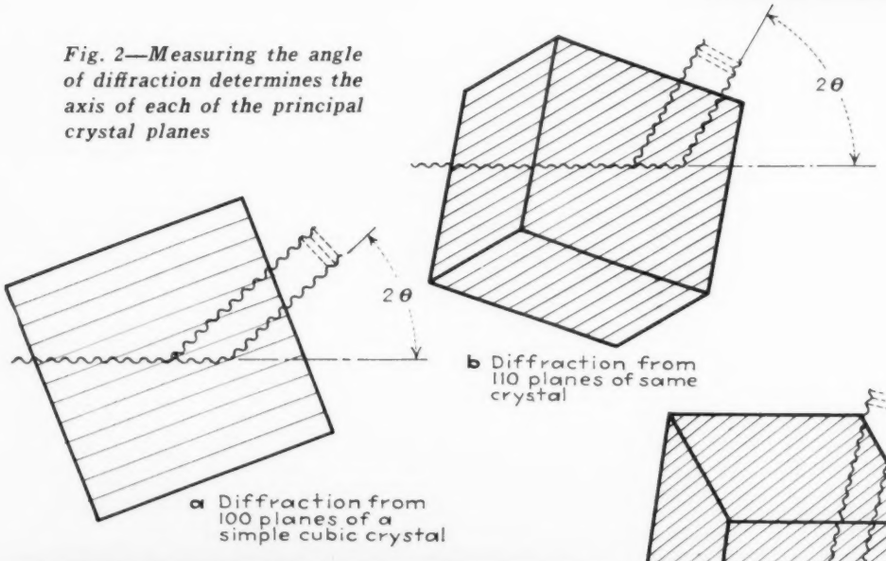
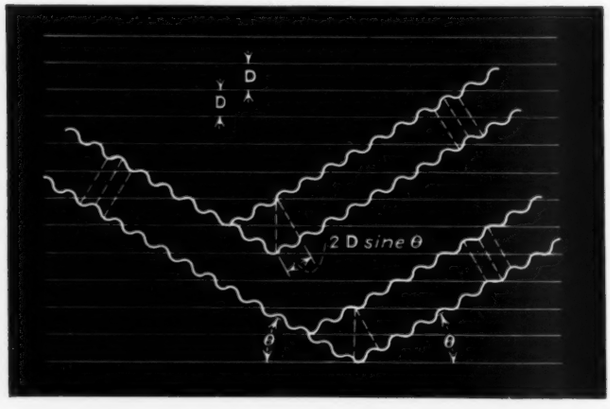


Fig. 5—An X-ray machine for diffraction analysis with water-cooled vacuum tube

Fig. 2—Measuring the angle of diffraction determines the axis of each of the principal crystal planes





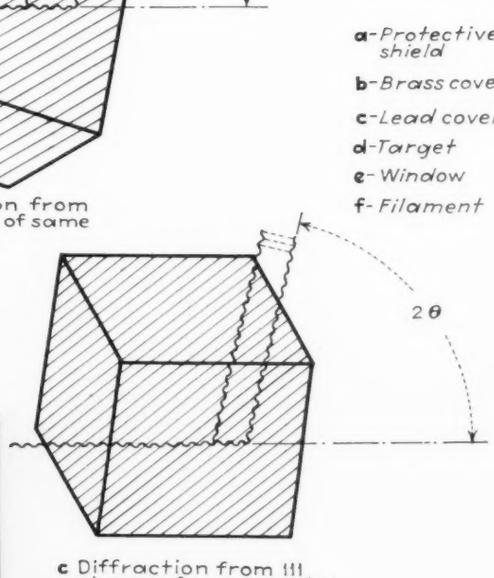


Fig. 3—Relation between plane spacing, X-ray wavelength and intensity of diffracted ray

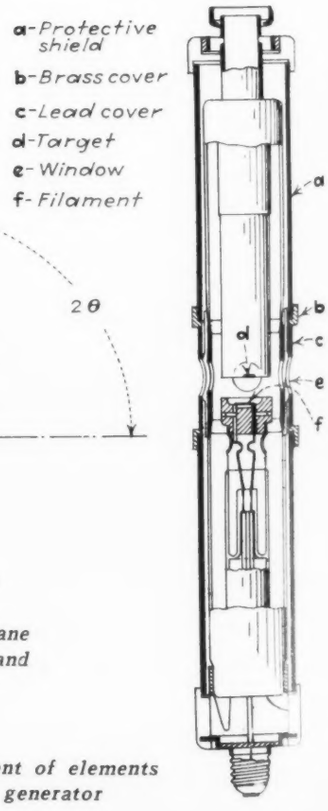


Fig. 4—Arrangement of elements in a typical X-ray generator

Bragg's Law of X-ray diffraction is given by the equation.

$$n\lambda = 2\,D \sin\theta$$

In Fig. 2 are shown the relative sizes of the diffraction angles of a particular wave length from the three families of planes illustrated in Fig. 1.

Shortly after Bragg's discovery, Mosely used this method to secure the X-ray spectra of several elements. When he measured the wave lengths, he discovered that certain X-rays characteristic of the elements, already known as the K-radiation, L-radiation, M-radiation, etc., were groups of lines having definite ratios of wave lengths. These ratios were found not only among the lines of each element but also between corresponding lines of different elements.

For any element the K-lines were shorter, more intense and more penetrating than the L-lines, the L-lines than the M-lines, and so on. From these observations Moseley determined that the wave lengths of corresponding lines of different elements were inversely proportional to the atomic number. This is the basis of identification of elements by X-ray diffraction.

The Laue method was extended to powdered and fine-grained materials and even to colloids by A. W. Hull in America and Debye and Scherrer in Europe. They replaced a single crystal by a specimen of fine-grained material. Under these circumstances the X-rays traverse a multitude of minute crystals lying at random. As each one constitutes a different three-dimensional diffraction grating for the X-rays for each spacing that exists in the material and for each wave length in the radiation, a cone of diffracted rays is formed about the central beam at an angle satisfying Bragg's Law. If characteristic wave lengths are present in the radiation, the cones resulting from these wave lengths will have intensities considerably greater than those caused by neighboring general radiation.

X-rays are emitted whenever matter is bombarded by cathode rays. The essential parts of an X-ray generating apparatus are a source of electrons proceeding from a cathode, which is a hot-wire filament in a vacuum tube, and a target or anode placed in the path of the cathode ray stream. The arrangement of these elements in a typical tube is shown in Fig. 4. Voltage applied between the cathode and the target accelerates the electrons to the required velocity. The quality of the rays can thus be controlled by the voltage across the tube, and the quantity by the temperature of the filament. The quality also depends upon the target material in which they are produced. The higher the atomic weight of the target material the greater the speed required for an electron to penetrate to the interior of an atom, hence, the higher the critical voltage necessary to excite characteristic radiation.

Measurement of the intensity of X-rays after diffraction or transmission through crystals is accomplished by an ionization chamber or by photographic method. The latter is probably less exact but it gives a complete record of the distribution of intensities over the entire area represented by the film and is both rapid and convenient.

Equipment used for X-ray diffraction work is shown in Fig. 5 for a typical installation. A high-tension transformer (not shown) supplies the necessary voltage to the X-ray tube. The one illustrated is a water-cooled vacuum tube. The metal center of the tube has four windows or apertures of Lindemann glass through which the X-rays pass to four cameras placed around the tube.

Two principal methods are used in X-ray analysis, transmission and surface reflection methods, both shown in Fig. 6. In the transmission method, the X-ray beam passes through the material to be examined, giving results which are mainly representative of the body of the material. They are particularly useful for materials that are reasonably transparent to the X-rays used. For more opaque materials, the specimen must be thin. In the surface reflection method the X-ray beam falls upon a surface inclined at an acute angle, giving results that are mainly representative of the surface layers.

(Typical diffraction patterns, and their interpretation in terms of design factors will be included in the second part of this article to appear in the July number.)

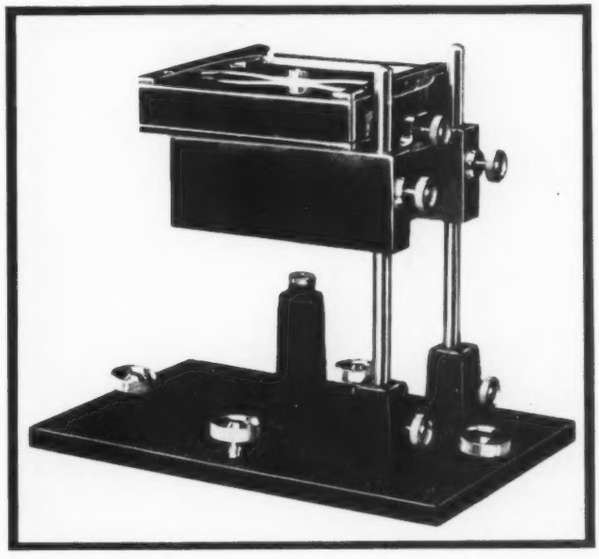
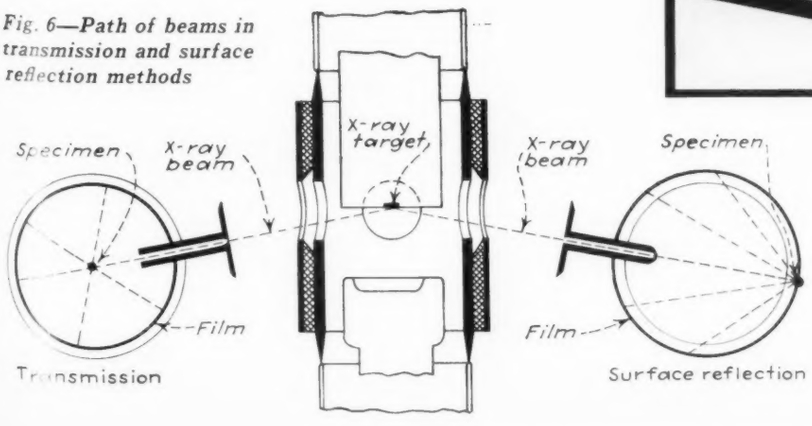


Fig. 7—In this pin-hole instrument the specimen is subjected to an intense beam that gives a well defined pattern in one or two hours. This instrument is suitable for high-speed high-voltage diffraction analysis for determining effects of cold working, heat-treatment, aging and strains

Fig. 6—Path of beams in transmission and surface reflection methods



Selection of Material for Jewel Bearings

B. W. ST. CLAIR
President, Mann Instrument Corporation

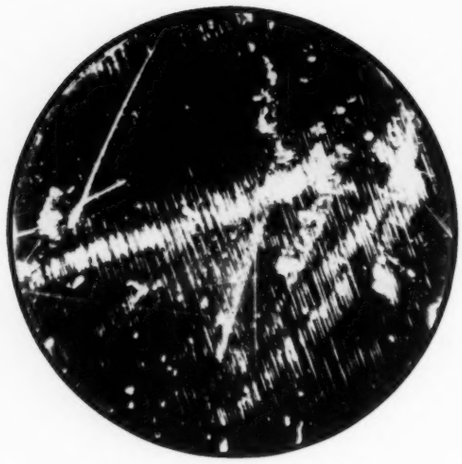


Fig. 1—Photomicrograph of a sapphire "end stone" showing sub-surface cracking from excessive pressure

Physical properties of 7 materials commonly used for bearings in precision devices, their relative value under different service conditions, and lubrication requirements

TABLE I

Material	Scratch Hardness (Moh)	Impact Hardness	Cleavage	Toughness	Composition	Wear Resistance
Glass	5.5–6	Low	None	Low		Low
Garnet	6.5–7.5	Low	None (Parting is common)	Fair	Complex Silicate	Fair
Agate	7	High	None	Very high	SiO_2	Moderate
Corundum (Ruby and Sapphire)	9	Moderate	None	Moderate	Al_2O_3	High
Diamond	10	High	Perfect in three directions	Very high	C	Very high

THE materials normally employed for bearings in precision devices and for other mechanical uses where great hardness is required are glass, garnets, agates, corundum (ruby and sapphire), and diamonds. There are wide variations in the physical properties of these so that the selection of a particular one for a particular purpose is desirable.

Characteristics that are needed in bearing materials of the jeweled type are: Chemical stability, toughness, high scratch hardness, high "wear" hardness, absence of easy cleavage, low coefficient of friction, and great impact strength. Table I shows some of the properties of the materials usually used for the jewel member of such bearings. All of these materials are quite stable chemically and they are also available in satisfactory quantities.

The weight to be carried, the mechanical forces involved, the form of the pivot, and character of rotation or oscillation are factors in the selection of a material for a bearing. In Table II relative load-carrying ability, wear resistance and impact resistance for various jewel materials is given in general terms.

As a guide to other possible uses, some fields for the successful application of these materials are given herewith.

GLASS—Devices where the load carried on the bearings is low and where there is comparatively little oscillation or rotation of the pivot. Examples are small electrical instruments and compasses. Steel is generally used as a pivot, although agate has been used as a knife edge on glass flats.

GARNETS—Inexpensive compasses and watches and applications such as ring stones in some electrical instruments. Steel is used as a pivot material against garnet.

AGATE—Planes and knife edges for precision balances, jewels for compasses, jewels for electrical instruments. Steel is generally used as a pivot material with agate jewels. Agate knife edges are used with agate planes in precision balances. Agate makes a fairly satisfactory "jewel" for oil-burner nozzles.

RUBY—Generally used in watches as color is an important item. Sapphire jewels are probably slightly better, but pale colors are not as attractive to the purchaser of a watch. Also used for some watt-hour meter jewels, compass jewels, some instrument jewels, and dial indicator jewels.

SAPPHIRE—Watt-hour meter jewels, instrument jewels, vees, ring stones and end stones, knives for precision surfacing, points for phonograph needles, compass jewels.

DIAMOND—Some watch bearings (more for sales purposes than for technical reasons) and watt-hour meter jewels for severe service.

In evaluating the characteristics of jewel materials, wear resistance and scratch hardness should not be confused. There is no general relationship between the two. For example, some of the metallic carbides are definitely much harder than sapphire, but in a pivot bearing a carbide jewel wears at least 100 times as rapidly as does a sapphire jewel. Agate has lower scratch hardness than many other available minerals, but pos-

sesses much greater toughness and wear resistance than most of the harder minerals. Impact resistance like wear hardness may not be related to scratch hardness or other physical properties. Diamond with great hardness has also great resistance to impact. Sapphire and ruby are superior to agate in wear and scratch hardness, but are inferior to it in toughness. Silicon carbide with greater scratch hardness than sapphire is much inferior to it in impact strength.

In Fig. 2 is shown an instrument for checking the scratch hardness of hard minerals such as are used for jewel bearings.

When using glass, the right kind must be selected and the method of fabrication must be correct. These are essential to the satisfactory use of this material. With low loads, less than 400 to 500 milligrams, in devices not subject to continuous rotation and with some degree of resilience in the mountings, glass renders quite satisfactory service. Some high precision devices have used glass bearings with relatively high loads, but the service conditions were under extremely careful control.

Where continual rotation of pivots, as well as low cost, low friction, and long life are essential, sapphire or ruby are the usual materials recommended. They have some unusual properties and some limitations so that each application requires individual consideration. Normally the load carried on sapphire jewels is less than 100 grams and seldom exceeds 500 grams. Bearing pressures of 30,000 to 200,000 lb. per sq.in. of contact area are usual, but loads and pressures several times these values have been used satisfactorily.

Lubrication of bearings materially reduces wear and is essential where there is continuous rotation of the pivot. Oil, either as a film or in abundance, increases rather than decreases the friction. Hence, if the resistance to rotation must be a minimum, the bearings must be operated dry. For example, jewel bearings in electrical indicating instruments are operated without lubricant. But the bearings of watches and watt-hour meters require a satisfactory lubricant and the absence or failure of lubrication in these bearings results in cutting or wear of both pivot and jewel and a quick failure of the device. The presence of oil does not prevent wear entirely but it does delay its initiation and reduces the rate at which it progresses. The selection of a suitable lubricant for a jeweled bearing service is as important as the selection of suitable materials and dimensions for the pivots and jewels.

Sapphire and ruby, while best known as gem materials, are not of rare occurrence. They are found in some quantity in many localities, both in this country and abroad. The principal localities from which usable quantities of satisfactory sapphire or ruby are obtained are Ceylon, Siam, Queensland, and Montana. Most of the sapphire used abroad in jewel bearings is manufactured, and is known as "synthetic sapphire." Most bearings used in American-made watches are synthetic ruby, but most bearings used in electrical meters and instruments in America are of natural sapphire. Most sapphire and ruby gems cut today are of synthetic material.

The conditions under which the bearings work should control the selection of the kind of sapphire or ruby, which is available in three general types. Natural sapphire and ruby occurs as an igneous and also as a metamorphic or secondary mineral. The Montana sapphires can be considered as of igneous or primary origin, although all mineralogists will not agree with this statement. The East Indian sapphires and those from Queensland are of metamorphic origin with crystallographic tendencies that differ from those of the Montana sapphires. The synthetic sapphire is made in a number of European plants, all of which use the same general method of manufacture.

For many purposes the synthetic sapphire is sufficiently good, especially if the weight carried is light and the device is not subject to severe shock. The higher impact and wear resistance of natural sapphire makes it more useful for many particular purposes that the artificial sapphire cannot fill. The advent of the synthetic material and the intense competition that exists in its manufacture has served as an effective check on price-

TABLE II

Material	Weight That Can Be Carried	Pivot Shape	Resistance to Wear With Continuous Rotation or Oscillation	Impact Resistance
Glass	Low	Sharp	Low	Low
Garnets	Low	Sharp	Fair	Low
Agate	High	Sharp or blunt	Moderate	High
Corundum (Sapphire and Ruby)	Moderate to high	Sharp or blunt	High	Moderate
Diamond	High	Sharp or blunt	Very high	High

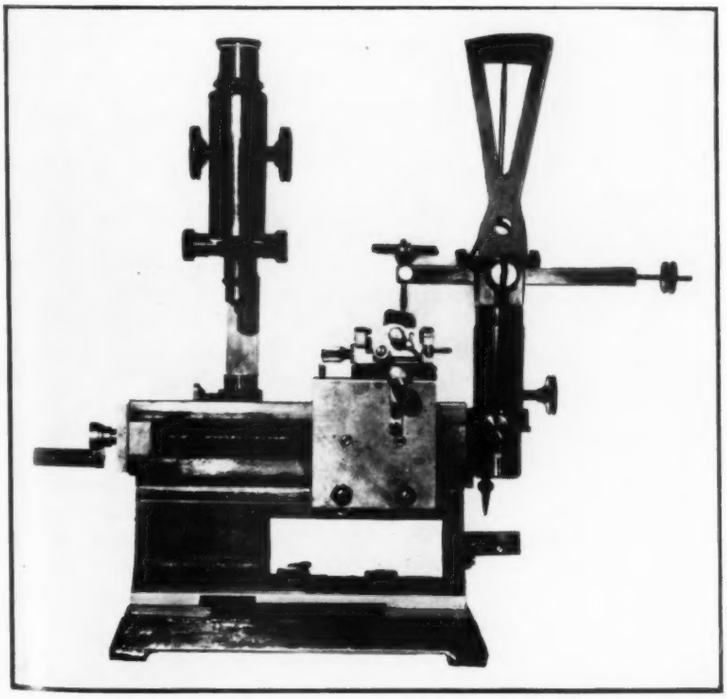
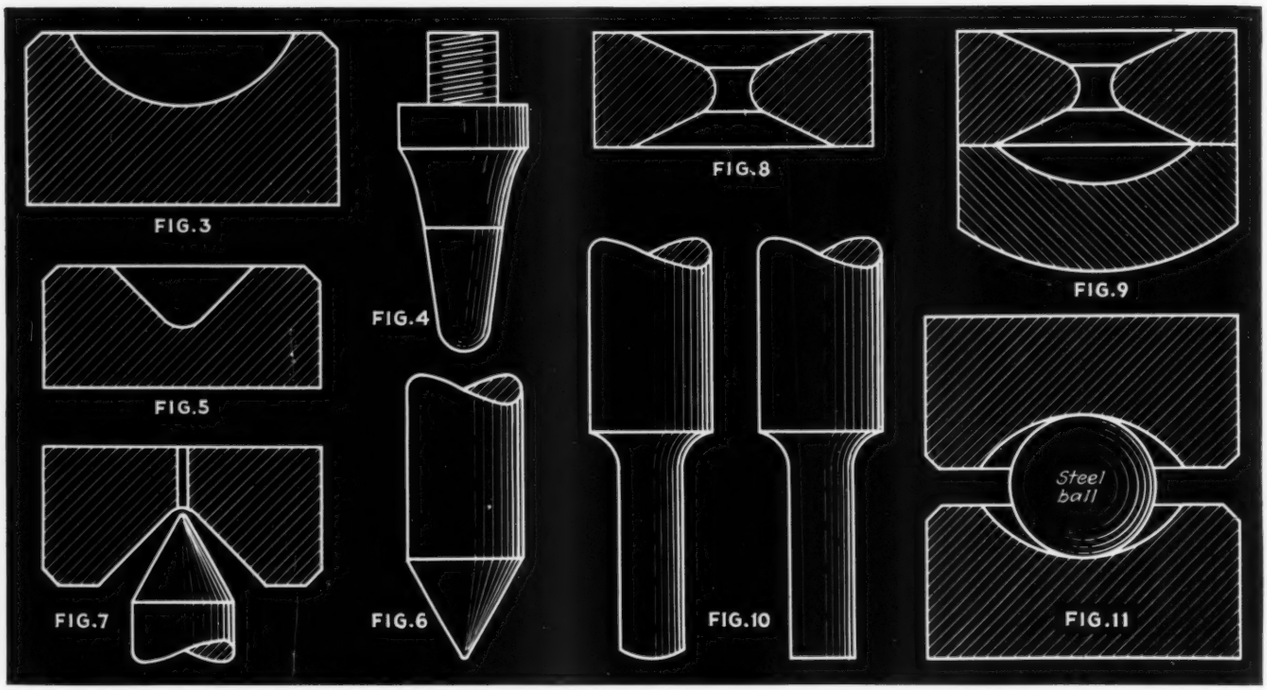


Fig. 2—Instrument for checking the scratch hardness of materials for jewel bearings



Some usual forms of jewel bearings and pivots. The pivot Fig. 4 is used with jewel Fig. 3; pivot Fig. 6 is used with Figs. 5 and 7, and the pivot in Fig. 10 is used with Figs. 8 and 9. Fig. 10 shows a steel ball between two jewels, a type of jewel bearing used in watt-hour meters

raising tendencies of those who control the sale of the natural material.

In general the service expected of jewels in watches is not severe and the synthetic material is satisfactory for the purpose. In small electrical instruments where the armatures are light and the impact forces moderate it is generally quite satisfactory. Instruments subjected to severe vibration as in aircraft service will probably prove more satisfactory with natural sapphire than with synthetic sapphire. Instruments for unusually precise service, where the slightest variation in friction caused by wear or mechanical damage to the bearing is fatal, have greater assurance of long life with natural than with the synthetic material.

Those who have worked sapphire and ruby in large quantity recognize definite differences in natural stones and have learned to differentiate between tough and brittle unworked stones. For exacting or severe services, bearings should not be bought on a price basis.

A common cause of rejection and of failure in sapphire and ruby bearings is caused by a peculiar subsurface cracking called "pressure parting." Over-pressure or impact may cause the appearance of these fine lines parallel to the base crystal plane of the sapphire. Fig. 1 is a photomicrograph of a polished "end stone" of sapphire badly pressure-parted by excessive pressure used in exploring the surface with a blunt pivot.

Agate, a cryptocrystalline material, is of wide occurrence. Much of the material used for bearings is of South American origin. It must be carefully selected before cutting.

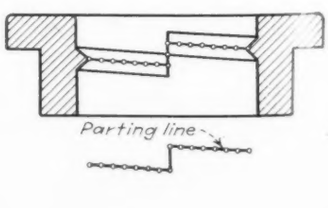
Garnets, like agate, are common minerals and occur in a wide range of colors. There are at least seven kinds of garnets known to the mineralogists. Those used for jewels are generally grossularite, almandite or pyrope.

In Figs. 3 to 11 are shown some usual forms of jewel bearings. Sizes and proportioning are dependent not only on the type of bearing used, but also on the jewel material, load, impact and other service factors. Design of the bearings is a specialized art and the average designer should consult the jewel bearing manufacturer rather than to attempt to develop his own designs.

Internal Thread Molded Without Using a Screw Core

Internal threads in molded plastics or die castings are usually made by using a threaded core which must be screwed out after the part comes off the press and then replaced in the mold, thereby greatly slowing up production.

A simple design of single thread is shown in the February number of *VDI*, the publication of the Vereines Deutscher Ingenieure, and is illustrated here. Being only a single turn of thread, it is possible to mold it without using a threaded core by making the parting line of the core as shown in the illustration. This type of design can be used for both molded plastics and die casting when the load is small enough to be supported by a single turn of thread.



For a single turn internal thread, the mold core is parted as shown

How to Make Alignment Charts

M. G. VAN VOORHIS

Application of either parallel or perpendicular solution lines in the construction of Z-charts and parallel line nomograms with instructions on the ascending direction of the scales

PART IV

THERE are a number of arrangements in which nomograms can be shown. When equations contain four or more variables, the scale lines can be drawn in both vertical or horizontal positions. The solution lines do not intersect at a common point but are either parallel or perpendicular to one another. One advantage of this is that it avoids the confusion resulting from four or more parallel scale lines. Such a chart is dependent upon a guide to solution or a key sketch. The question of which two scale lines should be crossed by a given solution line is obvious in nomograms laid out according to the following plan.

Nomogram for $f_1(x) \pm f_2(y) = f_3(u) \pm f_4(v)$

When laying out a nomogram having perpendicular solution lines as shown in Fig. 21, two parallel lines are subdivided uniformly with scales of $f_1(x)$ *and* $f_2(y)$ ascending in opposite directions if the sign is plus and in the same direction if the sign is minus. The size of the function scale units must be the same.

The u and v scales are drawn parallel to each other, and may be either parallel to the x and y scale lines or perpendicular to them. Their location is independent of the first pair of lines. The size of the $f_3(u)$ and $f_4(v)$ scales must be the same and their relation to the size of the $f_1(x)$ and $f_2(y)$ scales is determined by the rule: $m_x/m_u = d_1/d_2$, where

m = length of function scale units designated by subscript
d_1 = distance between the x and y scale lines
d_2 = distance between the u and v scale lines

Either line is subdivided with a uniform scale of $f_3(u)$ within its limits and ascending in the same rotational direction as the $f_1(x)$ scale, as illustrated in Fig. 22 for the equation $x + y = u - v$. The $f_4(v)$ scale ascends in a direction opposite to the $f_3(u)$ scale if the sign is plus and in the same direction if the sign is minus.

The position of the $f_4(v)$ or v scale on the line in Fig. 21 is relative to some starting point determined by selecting a value within its range and determining values of the other three functions which will satisfy the equation. A line drawn across the $f_1(x)$ and $f_2(y)$ scales at the determined values will give the slope of a line which, drawn through the third known point, will locate the selected value of the fourth scale.

Assuming that $v = 15$ is the starting point, any values of x and y are selected such as 5 and 50. Then $u = (x^2 + y + 3v)/2 = (25 + 50 + 45)/2 = 60$. The solution lines then locate 15 on the v scale. After determining the $f_4(v)$ scale, all function scales are repiaced with scales of the corresponding variables as described under "Nomogram for $f_1(x) \pm f_2(y) = f_3(z)$" on page 18 of the January number.

In Fig. 23 is shown why parallel lines may be used to solve a nomogram. At c the scales ascend in opposite directions. Any line ab crosses these scales and the dotted line cO is drawn parallel to it through zero of one of the scales. It is immediately obvious that any other parallel line passes through figures giving the same sum. At g the scales ascend in the same direction and by similar reasoning the lines parallel to any random line ab produce constant differences.

To transfer constant sums and differences to a second pair of scales, a second condition is imposed, namely, in changing from one constant sum or difference to another, the angle between the two different solution lines in each case must be the same. This is illustrated in h and k. Because the second pair of lines are closer together than the first pair and the solution lines make the same angle, a smaller scale is required for the lines that are closer together. Therefore, $5m_1/d_1 = 5m_2/d_2$ in the triangles formed.

Nomogram for $f_1(x)\ f_2(y) = f_3(u)\ f_4(v)$
or for $f_1(x)/f_2(y) = f_3(u)/f_4(v)$

The nomogram in Fig. 24 is another form of the same equation used in Fig. 19, page 103, March number. Two parallel lines are subdivided with logarithmic scales of $f_1(x)$ and $f_2(y)$. They ascend in opposite directions if the functions are multiplied, and in the same direction if one function is divided by the other. The size of the function scale cycles must be the same.

For the u and v scales, two lines are drawn parallel to each other, and either parallel to the x and y scale lines or perpendicular to them. Their location is independent of the first pair. The size of the $f_3(u)$ and $f_4(v)$ cycles must be the same and their relation to the size of the $f_1(x)$ and $f_2(y)$ cycles is determined by the following rule:

$$n_x/n_y = d_1/d_2$$

n = length of the function scale cycles designated by subscript
d_1 = distance between x and y scale lines
d_2 = distance between the u and v scale lines

Either line is subdivided with a logarithmic scale of $f_3(u)$ within its limits and ascending in the same rotational direction as the $f_1(x)$ scale as in Fig. 22. The $f_4(v)$ scale ascends in a direction opposite to the $f_3(u)$ scale if the functions are multiplied and in the same direction if the functions are divided. The position of the function on the line is relative to some starting point determined by selecting a value within its range and determining values of the other three func-

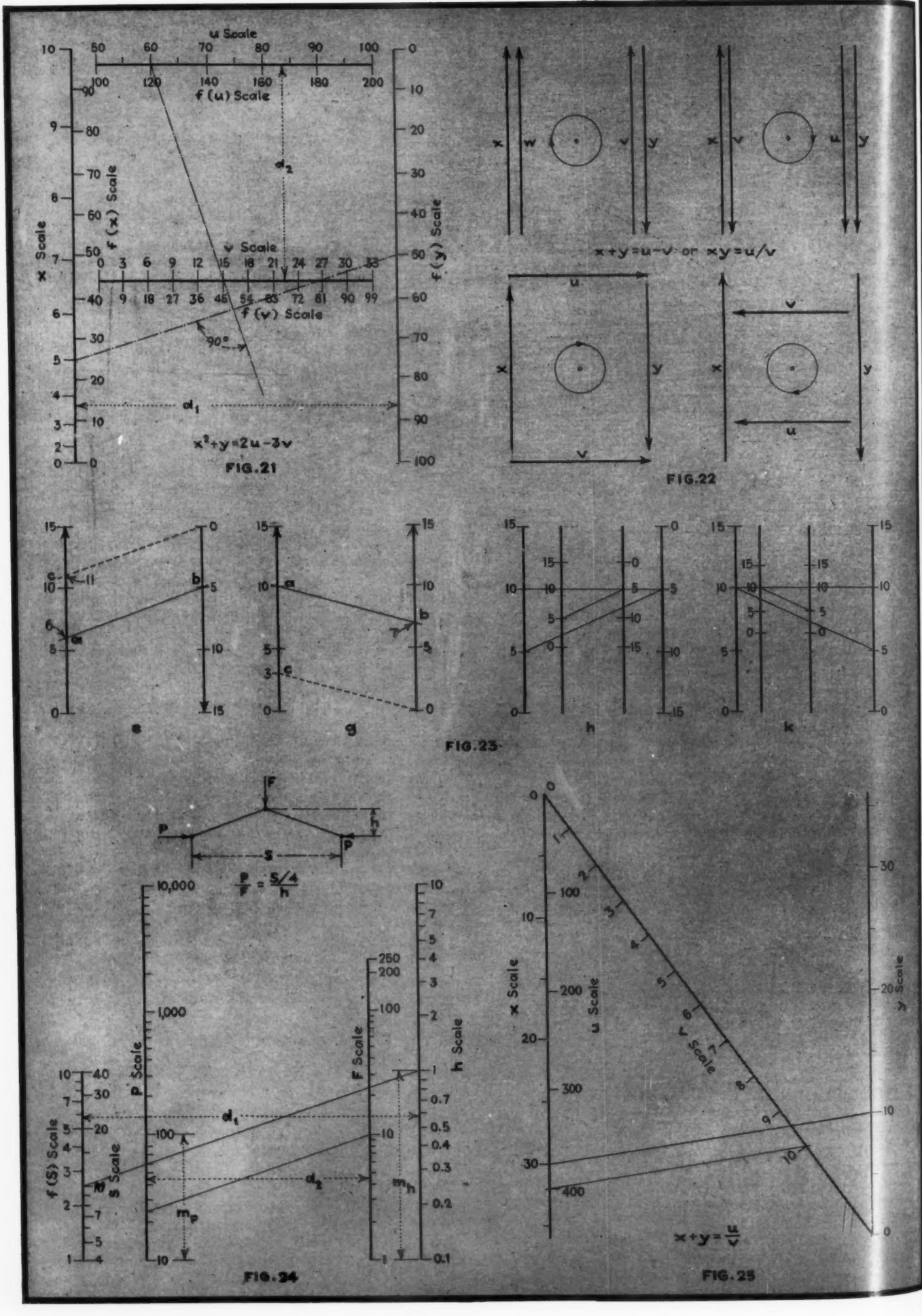


FIG. *Locat v scal ent o scale*

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tions which will satisfy the equation.

A line across the $f_1(x)$ and $f_2(y)$ scales at the determined values will give the slope of a line which, drawn through the third known point, locates the selected value on the fourth scale. After determining the $f_4(v)$ scale, all function scales are replaced with scales of the corresponding variables as described under "Nomogram for $f_1(x) \pm f_2(y) = f_3(z)$," page 18, January number.

To illustrate the nomogram for $f_1(x)/f_2(y) = f_3(u)/f_4(v)$ in Fig. 24, the toggle joints with equal arms act in the relation of $P/F = S/4h$ where P is the pressure resulting from a force F, and S and h are dimensions as indicated in the diagram. $P = 10$ to 10,000 lb.; $F = 1$ to 250 lb.; $S = 4$ to 40 in. and $h = 0.1$ to 10 in. If $f(S) = S/4$, $f(S) = 1$ to 10. Scales of $f(S)$ and h are made as large as the space allows with equal length cycles and ascending in the same direction. The P scale, having three cycles to two of the h scale, must be drawn to a smaller scale, not larger than 2/3 the size of the h cycle. Therefore the distance between the P and F scale lines must be not more than 2/3 the distance between the S and h scale lines. In other words, assuming $m_h = 1$, and $m_p = 2/3$, if $d_1 = 1$, then $d_2 = 2/3$ from the given proportion.

The P scale is then drawn with this shortened cycle and the point $F = 1$ selected on the F scale. When $h = 0.1$ and $f(S) = 1$, $P = 10$. A line through the lower scale ends drawn through $P = 10$ locates 1 on the F scale. The scale of F can then be drawn with the same cycle as the P scale, ascending in the same direction. With increased familiarity with the method it may not be necessary to produce both the function scale and the scale of the variable.

FIG. 21
Location of parallel u and v scale lines is independent of parallel x and y scale lines

FIG. 22
Scales ascend in same rotational direction when functions are subtracted or divided, and in opposite directions when functions are added or multiplied

FIG. 23
Application of the principle illustrated in Fig. 22 is shown at e and g. At h and k is shown how parallel solution lines are used

FIG. 24
Nomogram illustrating the application of equation $f_1(x)/f_2(y) = f_3(u)/f_4(v)$ for toggle joints with equal arms

FIG. 25
Z chart construction of $x + y = u/v$ showing graphically how uniformly divided diagonal scale is located

Nomogram for $f_1(x) + f_2(y) = f_3(u)/f_4(v)$

Parallel solution lines can also be applied to the Z chart for an equation in the form $x + y = u/v$. To lay out such a nomogram as shown in Fig. 25, the two parallel lines are subdivided uniformly with scales of $f_1(x)$ and $f_2(y)$ so that they ascend in opposite directions. The size of the function units must be the same. The diagonal line is drawn between the zeros of the two scales.

The u scale is obtained by first subdividing the opposite side of the $f_1(x)$ scale with a uniformly divided scale of $f_3(u)$ so that the zeros of both scales coincide. The scale may be as large as the space allows.

A uniformly divided scale of $f_4(v)$ may be located graphically on the diagonal line by subdividing, with equal divisions, the line between zero, which coincides with zero of the $f_3(u)$ scale, and its upper limit. The upper limit of the $f_4(v)$ scale can be located by drawing a line through values of $f_1(x)$ and $f_2(y)$ the sum of which equals $f_3(u)_{max}$ divided by $f_4(v)_{max}$. A parallel line through $f_3(u)_{max}$ on the scale will locate $f_4(v)_{max}$ on the diagonal line. Thus $f_3(u)_{max}$ divided by $f_4(v)_{max}$ equals $400/10 = 40 = 30 + 10 = 25 + 15$ and other values totaling 40. A line drawn through $u = 400$, parallel to the line through $x = 30$ and $y = 10$, locates $v = 10$ on the diagonal line.

The size of the $f_4(v)$ scale unit m_v may be computed from the $f_3(u)$ scale unit and the number of units, k, of the $f_1(x)$ scale which may be placed on the diagonal line. Thus, $m_v = km_u$ so that in Fig. 25, $k = 44.41$, k being the measured length of the diagonal in x units.

The application of parallel solution lines to the Z chart is further explained by reference to Fig. 26 in which the lines CD, AB, and NO' are parallel. It is evident from similar triangles that $(OA + O'B)/OO' = OC/OD$ since $O'B = AN$. If $x = OA$, $y = O'B$, $u = OC$, $v = OD$, and OO' is a constant, k, the equation becomes, $(x + y)/k = u/v$. By multiplying both u and v by any constant the equality is unchanged so that the scales may be made to any size independent of the x and y scales.

The constant, k, has been combined with v in the procedure as if the equation were written, $x + y = u/(v/k)$. But since k is included in the proportion with x and y, k is measured in the same units as x and y and may be interpreted as the number of $f(x)$ or $f(y)$ units in the length of the diagonal. The length of the unit, v/k, would be the same as the unit of u. Therefore, $m_v = km_u$. The same, of course, applies to units of $f(v)/k$ and $f(u)$ so that $n_v = kn_u$.

If the sign between $f_1(x)$ and $f_2(y)$ is negative, the $f_2(y)$ scale extends below the point O' in Fig. 26. An example of this type is shown in Fig. 27, a chart for determining bolt diameters. The construction line, K, is the diagonal line. In this instance, the scales corresponding to u and v are on lines which are perpendicular to the scale corresponding to x, and the diagonal line. The functions are: $f(D) = D$, $F(T) = 1.3/T$, $f(L) = 1.125\sqrt{L}$, and $f(f_t) = \sqrt{f_t}$. In the example a 1-in. diameter bolt having 8 threads per in., under a tension of 10,000 lb. has a fiber stress of 18,000 lb. at the root of the thread.

Nomogram for $\dfrac{x+y}{x-y} = \dfrac{f_1(u)}{f_2(v)}$ or

$$\frac{f_1(x) + f_2(y)}{f_1(x) - f_2(y)} = \frac{f_3(u)}{f_4(v)}$$

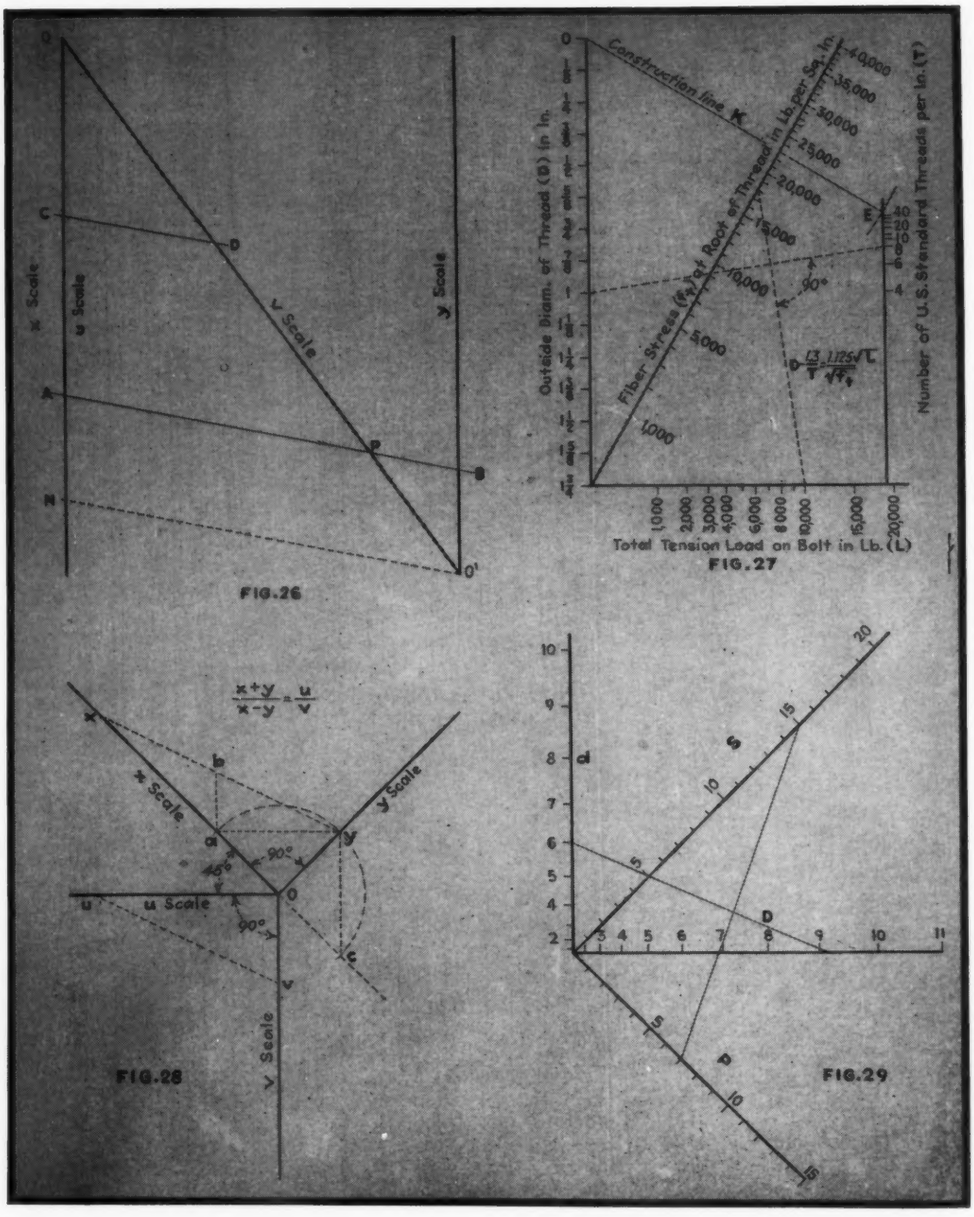
When laying out a nomogram for such an equation four lines are drawn as shown in Fig. 28 intersecting at a point such that the angles between successive lines are respectively 90 deg., 45 deg., and 90 deg. The two lines separated by an angle of 45 deg. are subdivided with uniformly divided scales of $f_1(x)$ and $f_3(u)$ of any convenient sizes independentiy of each other so that zero of each scale is at the intersection of the lines. A uniformly divided scale of $f_2(y)$ of the same size as the $f_1(x)$ scale is placed on the line at right angles with the $f_1(x)$ scale line so that zero is at the intersection. A uniformly divided scale of $f_4(v)$ of the same size as the $f_3(u)$ scale is placed on the line at right angles with $f_3(u)$ scale line so that zero is at the intersection. The function scales are then replaced with

FIG. 26
Similar triangles constructed with parallel solution lines can be used to prove the construction of the Z chart

FIG. 27
Nomogram with perpendicular solution lines for finding the fiber stress of a bolt at the root of the thread

FIG. 28
The four scale lines, radiating from a common intersection point, form angles of 90, 45 and 90 deg. respectively

FIG. 29
Nomogram of Lame's formula for determining the stresses in thick walled cylinders



scales of the variables. In this example the solution lines are parallel, but by swinging one pair of the perpendicular lines 90 deg. toward the other pair, less space is required and similar results are obtained with perpendicular solution lines.

This type of nomogram is of a more special character than other types which have been treated heretofore. In Fig. 28 is shown why the equation can be solved graphically.

In the similar triangles xcy and xab, $xc/xa = cy/ab$, the lines ay and ab are parallel to uO and vO respectively. The line uv was drawn parallel to xy. In the similar triangles aby and uvO, $ay/ab = uO/vO$. Since $cy = ay$, then $cy/ab = uO/vO$. Therefore $xc/xa = uO/vO$ and since $yO = cO = aO$ then

$$(xO + yO)/(xO - yO) = uO/vO$$

If $xO = x$, $yO = y$, $uO = u$, *and* $vO = v$, then

$$(x + y)/(x - y) = u/v$$

If u and v are multiplied by the same constant, the equality is unaffected and therefore the size of the u and v scales is wholly independent of both the x and y scales.

The procedure for this type of nomogram has been described for the instance where the solution lines are parallel but it is obvious that by swinging the u and v scale lines in Fig. 28 clockwise 90 deg. no change need be made in the development except that the solution lines are perpendicular to each other instead of being parallel.

The example given in the nomogram shown in Fig. 29 is for Lame's formula for stresses in thick-walled cylinders, and is of the form shown in Fig. 28. The external and internal diameters, D and d, are drawn in the same sized units and the stress and pressure, S and P, are also drawn in the same sized units.

In Part V of this series of alignment charts will be shown combinations involving both angular relationships and parallel or perpendicular solution lines.

QUESTION AND COMMENT

Beryllium Copper Molds for Plastics

To the Editor:

● In the April issue of *Product Engineering* on page 152 is a news items, "Beryllium Copper Molds Open New Uses for Plastics." On the following page in the last paragraph, the statement is made that beryllium-copper is particularly suitable for making molds for decorative designs because of the sharp definition that is obtained when the metal is cast. It also states that the ease of hardening the metal by heat-treatment does not warp the die or change its dimensions. The final statement is, "Of course the dies do not last as long as those made of tool steel or pack-hardened steel."

Relative to the latter statement, it might be quite possible to greatly increase the life of beryllium-copper molds by means of chromium plating them, although I cannot say at the present moment that I know of anyone who is now using chromium plated beryllium-copper molds. E. N. SCHMITT
New York, N. Y.

EDITOR'S NOTE: We are wondering if any of our readers have had any experience with chromium plating beryllium-copper molds for this or any other use.

Determination of Load Distribution

To the Editor:

● Designing engineers are usually in a position to specify the type and capacity of the power unit for the machine being developed. They consider the most destructive loading, maximum speed or maximum torque, proceeding on the assumption that all parts of the machine are rigid and then determine the load on each part of the machine. The unfortunate part of this analysis is the fact that reasonable deformations may seriously disturb the determined load distribution.

These conditions cause serious thought of how much is the value of data and knowledge concerning stresses, minimized by our lack of familiarity of load distribution throughout a machine. What is the immediate value of the information concerning stresses if we do not know the loads acting? Does not this bring out the point that more time, energy and money should be expended for research on the determination of the distribution of loads?

Although the basis of such research might be the application of the "theory of least work," this theory is far from completion in its development. On the subject of stresses our long standing theories of stress analysis are fundamentally correct, but they are woefully incomplete. Recent research has added to those fundamentals so that at the present time, if we knew the loads acting, it would be possible to closely predict the action, safety and satisfaction of new machines.

Therefore a development of the theory of least work for the determination of load distribution, accompanied by research work to confirm or alter the theory, would put the designer on a sound foundation.

It is fortunate that much of research work relative to stress analysis has been carried on for the past fifteen years or more. However, it would have been more successful had the load problem been carried along with it. It might be said that had the importance of the consideration of the load been realized at the time stress research was being so industriously extended, and, had the financial and physical resources been divided between the two phases of the problem, we undoubtedly would be far ahead of our present position in the design field. There is no desire to hamper any valuable research work but it is so apparent that one branch has been developed so far ahead of its running mate that we should stop and take cognizance of the situation and enthusiastically encourage research investigation dealing with the distribution of loads on machine parts. —F. A. MICKLE
Ann Arbor, Mich.

Investing Cork With Toughness

To the Editor:

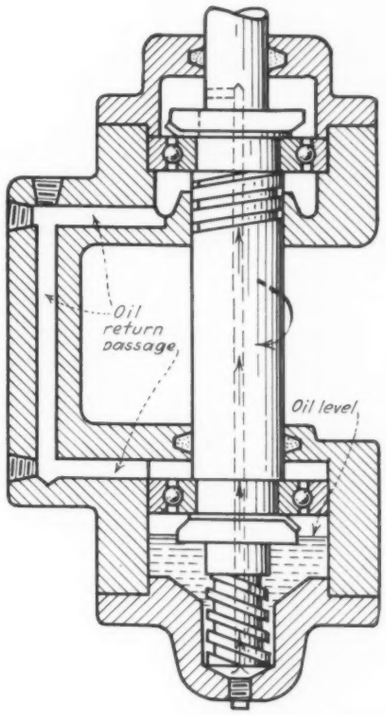
● We are all acquainted with the shock-absorptive powers of cork, and know that in certain respects it may be considered superior to most other materials for this purpose. One of the limitations of cork, however, is the fact that it is not as tough as other materials, and will not stand the strain in certain locations that other materials will. Where it is desired to use cork in such places, especially when it will be subjected to tensile strain, torsion or much flexure, it is quite practical and proper to use it in the form of a composition with rubber. In this manner, the inherent toughness of rubber is added to the natural advantages of the cork. —JOHN E. HYLER
Peoria, Ill.

Vertical Shaft Bearing Lubrication

To the Editor:

● The accompanying sketch shows a method of lubricating two ball bearings in vertical mounting as requested by Fred Adams in the March issue.

The oil is forced up through a drilled hole in the shaft by the screw pump on the bottom of and integral with the shaft, to the upper bearing. The oil is then returned by gravity to



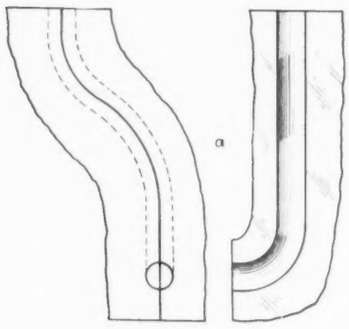
Oil is forced up through hole in shaft to upper bearing returning to reservoir by gravity

the sump through passages drilled in the casting. This passage leads to a position above the lower bearing thereby insuring lubrication at this point. Modifications can be made to the effect that when the bearings are not joined in such a way that the passages for returning the oil can be drilled as shown, the housings may be tapped and piping installed. The oil feed to the upper bearing can also be piped outside when deep hole drilling is not convenient. —W. E. SUMMERHILL
Cleveland, Ohio

Hopper Feed Chute

To the Editor:

● The feeding of small hardened cylindrical pieces from a hopper to an automatic grinding machine had been a source of trouble. At first the chutes were cast in two pieces as shown at (*a*) in the illustration. After smoothing up the semi-circular passages, the two pieces were bolted together. Being made of cast iron, the chute would soon



wear a sufficient amount, to allow the pieces being fed to turn end for end. Because of this reversed position of the pieces, the machine would automatically stop, causing a waste of time and thereby lowering production.

Brass tubing was then used in place of the cast iron. Although the smooth interior of the tube allowed the pieces to slide easily, this material also wore away too rapidly. The solution was, of course, to make the chute of hardened steel, but to mill out the pathway was too expensive.

A coiled spring finally solved the problem. A fairly heavy gage wire was used and the spring was tight wound, as shown at (*b*). It was flexible enough to assume the desired position when properly fastened. When assembled, the spring chute was coated with grease to facilitate sliding of the pieces. The problem of wear was overcome and the time and cost of manufacture was reduced materially by the use of this spring.

—A. M. HOLLAND
New York, N. Y.

Gear Pump

To the Editor:

● We are interested in knowing whether or not there is any standard formula by which the displacement of a gear tooth in a gear-type precision metering pump can be figured.—J.P.L.
Philadelphia, Pa.

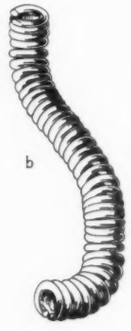
To the Editor:

● Herewith is a formula that I believe will be useful to J.P.L. of Philadelphia. If he really wants displacement per tooth, it will, of course be necessary to divide the final result by the number of teeth in the gear.

$$V = \frac{W}{4}\left([(N+2)/P]^2\pi - [(N-2)/P]^2\right)$$

N = number of teeth in one gear
W = width of gear teeth
P = pitch diameter
V = volume in cu.in. per rev.

—G. E. BREEZE
Highland Park, Mich.



A two-piece cast iron chute (a) was superseded by a compression spring (b) for feeding small cylindrical pieces from a hopper. Spring is coated with grease to facilitate feeding

Errata

● In the alignment chart for approximate ellipses on page 48 of the April issue, dimension *b* of the ellipse should have terminated at the center line, being for the semi-minor axis.

Theory of Photoelastic Analysis

To the Editor:

● We would consider it a great favor if you would suggest a list of what you consider to be the best references on the theory of photoelastic analysis. I have studied with much interest your articles in *Product Engineering* on this subject. —E. P. WHEATON
Alhambra, Calif.

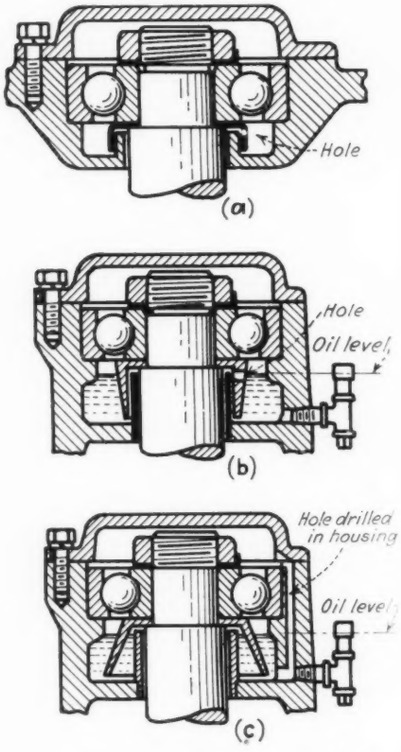
EDITOR'S NOTE: In addition to the series of articles published in *Product Engineering*, the photoelastic laboratory of Columbia University has prepared reports on various investigations of this subject, which may be of interest to product engineers. Reprints of ten papers are available upon application to Columbia University.

All literature pertaining to this subject, issued before 1931, is mentioned in the book "A Treatise on Photoelasticity," by E. G. Coker, and L. N. G. Filon, Cambridge University Press, London. This book may be obtained from the Macmillan Company, New York, N. Y.

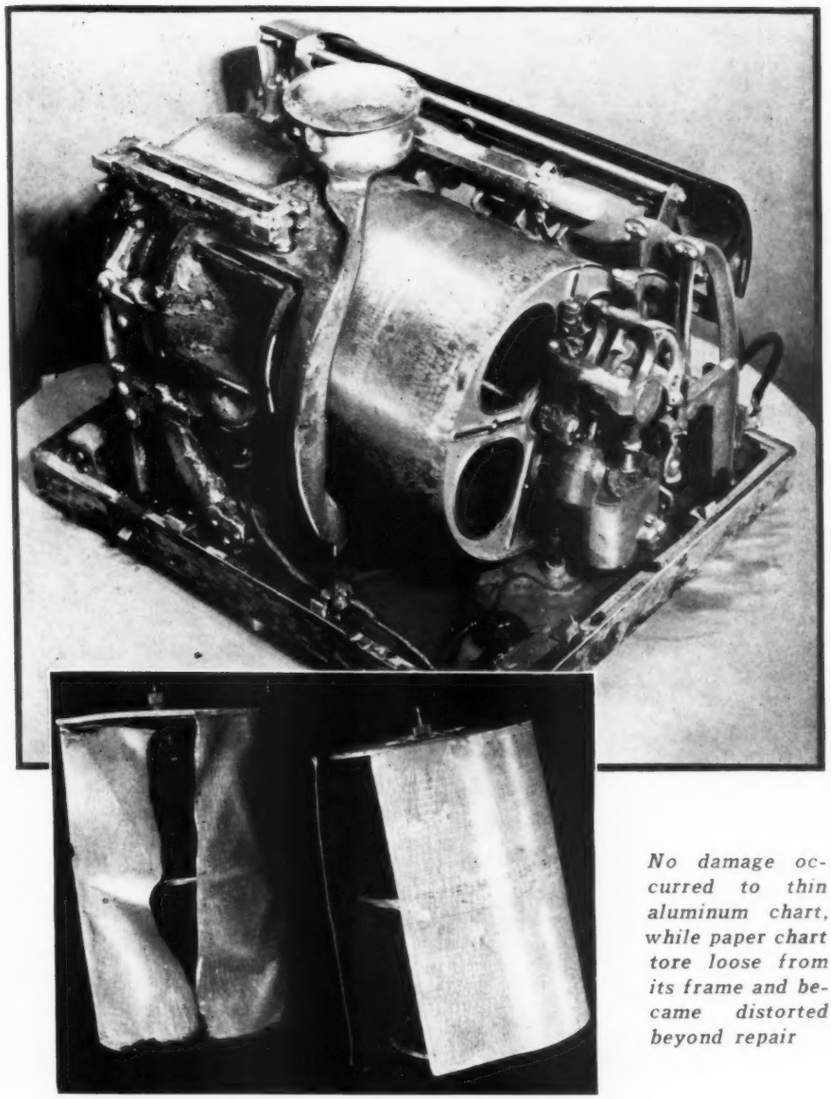
Vertical Mounting of Ball Bearings

To the Editor:

● With reference to the letter from Fred Adams, on page 108 of your March issue, we have had a great deal of experience with these vertical ball bearing applications where the oil is thrown up into the bearing. It is my own personal impression that these various devices all work by vaporizing the oil, the vapor lubricating the bearing. I believe this is true because I have seen a great variety of flingers and lifters and they all seem to work. By this method the amount of lift to the top bearing can be 6 in. or more. I know of one very high speed application on a router where this same



Three representative vertical mountings of ball bearings for oil lubrication



No damage occurred to thin aluminum chart, while paper chart tore loose from its frame and became distorted beyond repair

method is relied upon. The oil is fed to the lower bearing and the vapor lubricates the top bearing, but in this instance the design is arranged so the flinger on the seal produces a suction at the top bearing, actually sucking the oil vapor up to it.

The accompanying illustration shows three typical designs. Although designed for grease, the method shown at (a) can be used for oil also. The hole in the pressed steel cup prevents possible syphoning when the bearing is not rotating. The design at (b) is best suited for oil lubrication, the oil being lifted into the bearing by means of the inverted rotating cone. The drilled hole in the thrower acts in the same manner as described above. At (c) is shown an actual pumping arrangement whereby the oil is forced up through the drilled hole in the housing by the dish-shaped oil flinger.

We suggest that Mr. Adams' design could be made more reliable if the oil wells were made deeper so that they could withstand a wider variation in the oil level. Also he does not need the flipper he shows unless the speed is very slow. Normally a perfectly smooth exterior is satisfactory.

For very high speed applications we prefer a circulating wick system which has been used for as much as 6 to 8 in. lift. It has the advantage of allowing only a very small amount of oil into the bearing, and the oil is filtered continuously. However, it is somewhat more delicate and should not be resorted to except for very high speed applications.

—THOMAS BARISH
Assistant Chief Engineer
Marlin-Rockwell Corporation

Aluminum versus Paper

To the Editor:

● During the recent flood conditions at Johnstown, Pa., a number of Toledo weighing scales were under 15 ft. of water for two days. To ascertain the comparative damage resulting from immersion in water and mud, an old style porcelain scale and a new Plaskon Duplex scale were selected at random. The paper chart of figures in the former was damaged beyond repair in that it had torn from its frame and upon drying was distorted as is shown in the illustration.

Upon removal of the molded plastic case of the Duplex scale, the mechanism was found to be choked with mud and silt. This scale is equipped with a chart of some 95,000 digits etched on a thin sheet of aluminum. The chart is fastened to a frame forming a drum. After being washed with steam it was found that no damage had occurred to the aluminum type of chart.

—J. T. SLOSS
Pittsburgh, Pa.

EDITOR'S NOTE: The Toledo Plaskon Duplex scale mentioned above was described in the September 1935 issue.

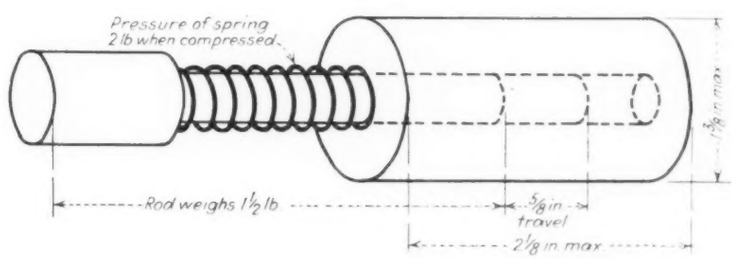
How Large a Coil?

To the Editor:

● I am in need of a coil to operate on 110 a.c. and d.c. for drawing in a plunger rod that weighs 1½ lb. Can some of the readers of P.E. tell me what size wire and how many turns is necessary to make a coil that will operate successfully? The plunger rod stays in for from 5 to 10 sec. and it does not matter if the rod gets warm.

If it is impossible to have a coil to operate on both a.c. and d.c. with equal efficiency, then what kind of a resistor, connected in series with the coil, will it be necessary for operating the coil on d.c.? The steel rod is drawn inward ⅝ in., the spring compressing to 2 lb. pressure. In the accompanying sketch is shown the allowable space.

—J. M. MARATECK



Wire size and number of turns required for coil not to be larger than 2¼ in. long by 1⅛ in. diameter

Electric Switches

B. B. RAMEY
Chief Engineer
Black & Decker Manufacturing Company

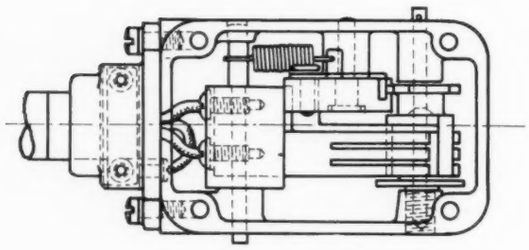


FIG. 1

Fig. 1—Trigger operated ratchet-type single pole switch, a design no longer in general use. An arrow stamped on the end of the shaft shows through a hole in the cover plate to indicate the position of the switch. Spring blades pressing on the faces of the square contact block give a snap action and hold the block in position.

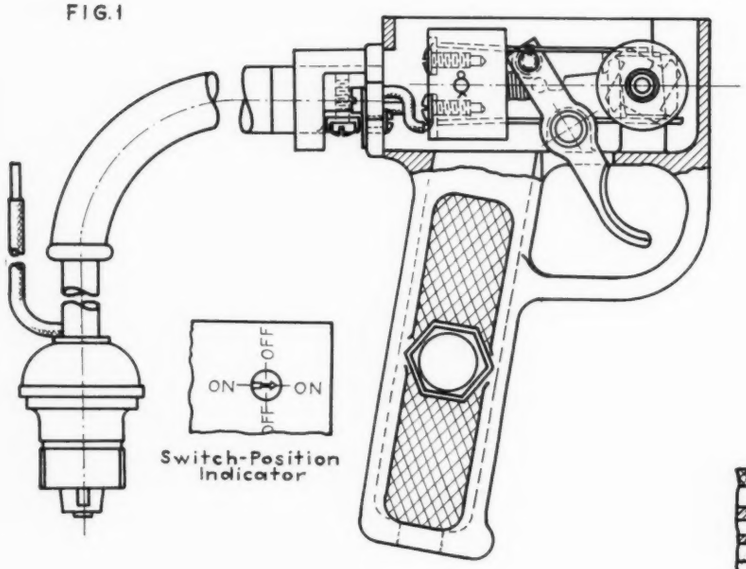


Fig. 2—Ratchet-type switch with double pole for 3-phase. Can also be used for single phase. The word "on" is stamped on diametrically opposite points on the ratchet wheel. With switch in "on" position, the word shows through a hole in the cover plate. A spring level snaps into the star wheel, giving quick snap action. As in Figs. 1 and 3, to open the switch a definite movement of the trigger is required.

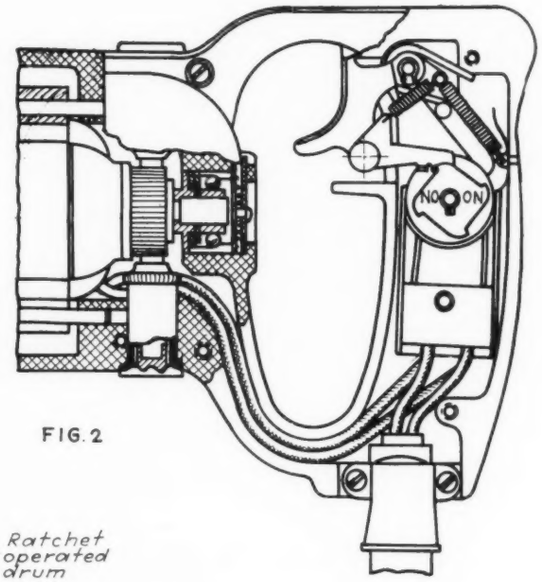


FIG. 2

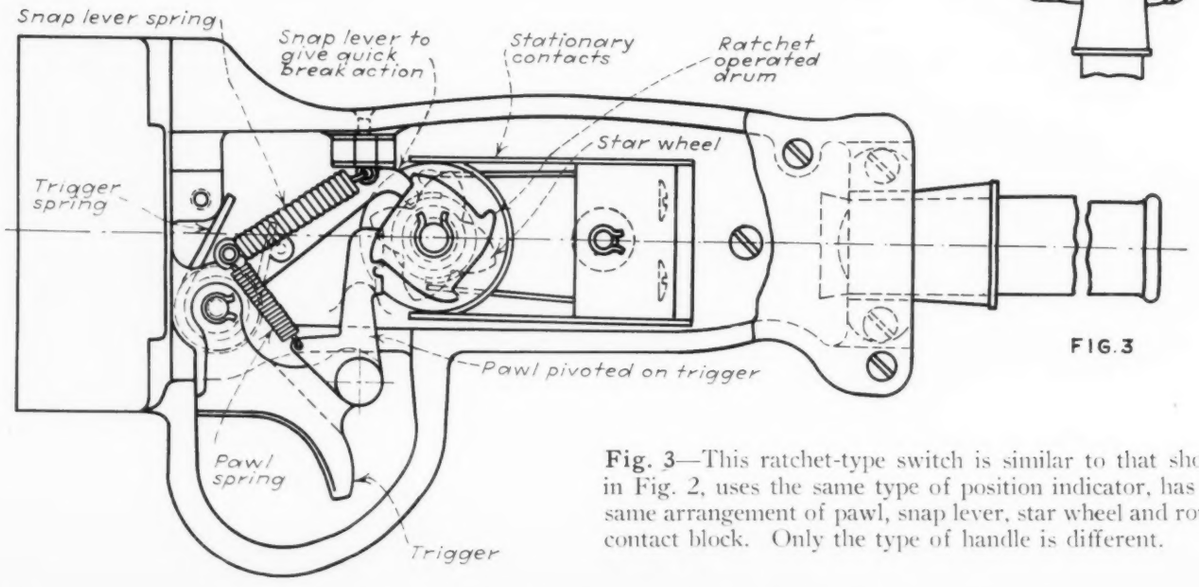


FIG. 3

Fig. 3—This ratchet-type switch is similar to that shown in Fig. 2, uses the same type of position indicator, has the same arrangement of pawl, snap lever, star wheel and round contact block. Only the type of handle is different.

and Switch Mountings—I

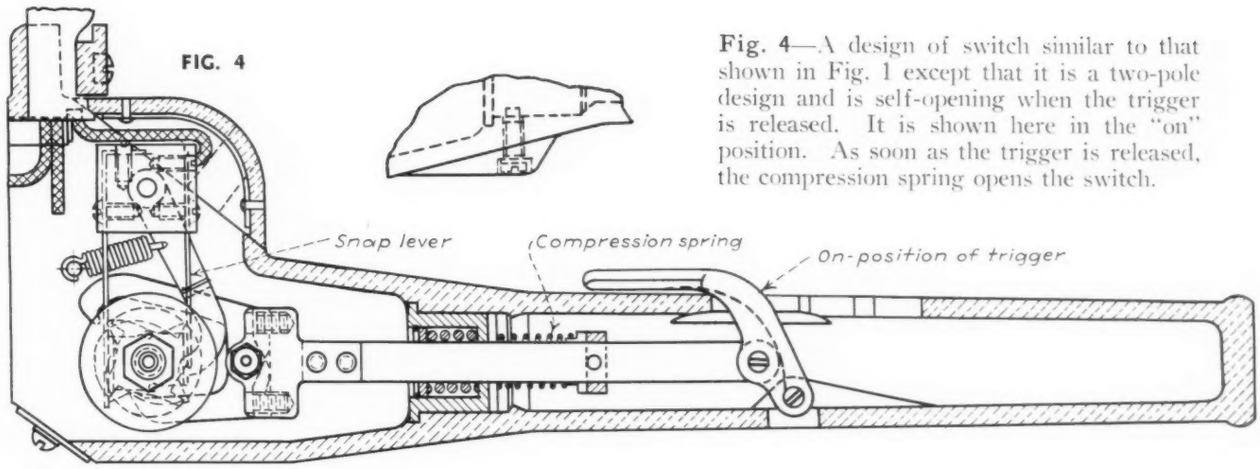


Fig. 4—A design of switch similar to that shown in Fig. 1 except that it is a two-pole design and is self-opening when the trigger is released. It is shown here in the "on" position. As soon as the trigger is released, the compression spring opens the switch.

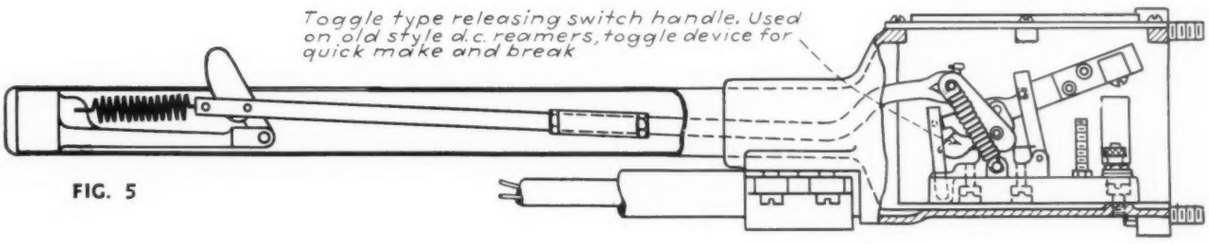


Fig. 5—A toggle-type self-opening switch used on old style d.c. reamers. The tripper is pushed forward until the line of pull of the spring passes the dead center of the link to which it is attached. The spring then pulls the switch closed. Upon releasing the trigger the mechanism returns to the position shown, the switch snapping open when the toggle spring passes dead center.

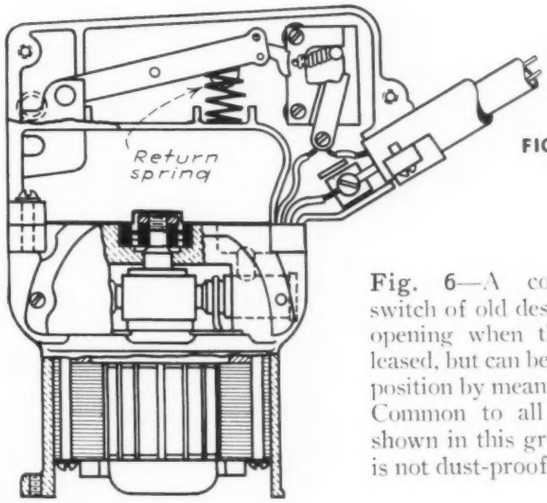


Fig. 6—A conventional type switch of old design which is self-opening when the trigger is released, but can be held in the closed position by means of a locking pin. Common to all of the switches shown in this group of designs, it is not dust-proof.

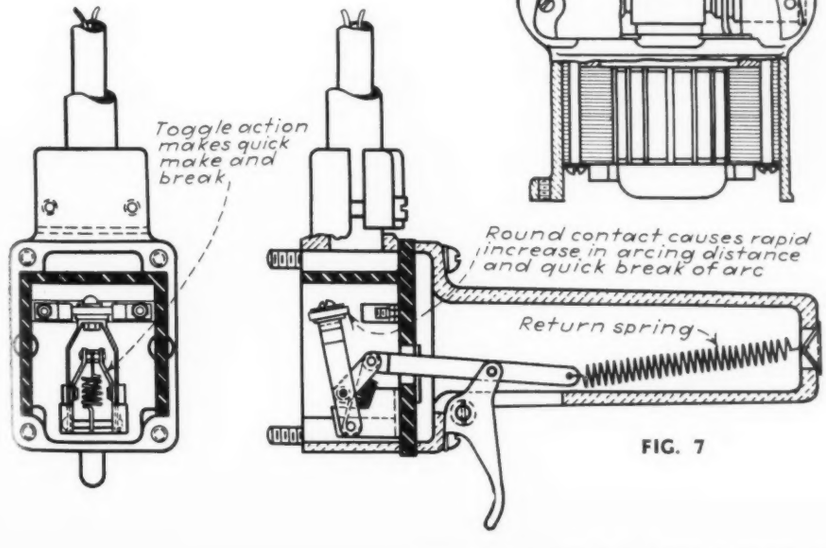
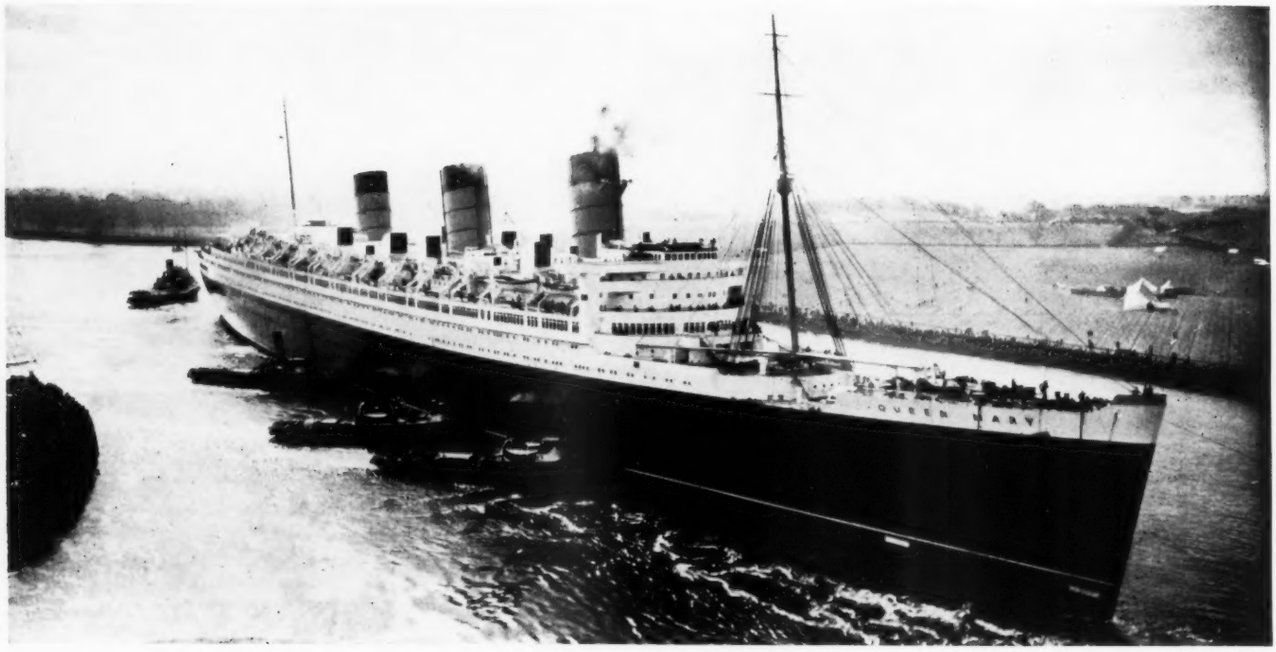

Toggle action makes quick make and break
Round contact causes rapid increase in arcing distance and quick break of arc
Return spring
FIG. 7

Fig. 7—A special design of built-up switch of the self-opening type and provided with a locking pin, similar to that shown in Fig. 5. Common to all of the designs shown here, the switch is now obsolete in favor of fully-inclosed and easily replaceable switch units.



Schrage Photo

Size, speed, dignity and power—all of these qualities are characteristic of the Queen Mary, sailing May 27 from Southampton to New York

NEWS

Queen Mary

THE NEW Cunard White Star liner No. 534, better known as the Queen Mary, will arrive in New York on her maiden voyage some time in June. Built by Messrs. John Brown & Company, Ltd., of Clyde Bank, Glasgow, she was launched on September 26, 1934.

After thorough researches on the hull form, it was decided to use the sharp prow in preference to the bulbous bow such as used by the Normandie, Bremen and other late transatlantic liners. It is interesting to know that more than 7,000 experiments were made on numerous models to determine the best lines. During these tests the models traveled a total distance of more than 1,000 miles in the test tank.

With a length of 1,018 ft., a beam of 118 ft., and 135 ft. high from keel to superstructure, this massive hull comprises 12 decks.

On either side of the double bottom rise the two shells, an inner and an outer skin, running the full length of the machinery spaces of the ship, in places to a height of nearly 40 ft. The space between the two skins is divided into water-tight compartments, totalling nearly 116. The main subdivisions of the ship comprise in all 18 water-tight bulkheads.

An unusual feature in the construction of the hull has been the use of special high-elastic limit steel. The total weight of metal in the hull and machinery will exceed 50,000 tons. More than 10,000,000 rivets fasten the steel plates together.

About 2,000 port holes and windows are in the hull, requiring more than 2,500 sq. ft. of glass, in panes ranging from 1 ft. in diameter to large oval panes more than 2 ft. in height.

The rudder itself weighs more than 140 tons, the largest ever constructed for any ship. Two doors are fitted into the sides of the rudder, which has permanent steel ladders inside, to enable officials to get to any part of the great structure for inspection purposes.

Indicative of the size of this vessel is the fact that in the first class restaurant and foyer there could be placed the hull of the first Cunard steamer "Britannia," 207 ft. long, together with the three vessels that comprised Columbus' fleet on his voyage of discovery to America.

The Queen Mary will be driven by a system of Parsons single reduction geared turbines supplied with steam from high-pressure water tube boilers. There will be four propellers each of which is to be driven by an independent set of machinery, comprising a large gear wheel driven by four turbines. Each set of engines will have an independent condensing plant, consisting of a large surface condenser with the necessary circulating and condensate pumps.

Every single one of the 257,000 blades for the turbine has been tested and fitted by hand. Each of the four gear wheels is 14 ft. in diameter and weighs nearly 80 tons. The gear cases weigh 200 tons. Steam is supplied by 27 boilers containing a total of 160,000 tubes, in addition to the 60,000 tubes in the condensers. Fuel oil is used. Each of the four propellers weigh about 35 tons.

Aside from the propulsion engines, there will be seven turbo-generators delivering nearly 10,000 kw. and capable of supplying sufficient electrical energy for a town of 150,000 people.

Much of the ship is air-conditioned. To supplement the warm air heating, an electric heater is supplied in each of the first class staterooms. Third class accommodations are also air-conditioned, as are the public rooms. The ship is kept on her course by a powerful electric-hydraulic four-ram steering gear. Anchors weigh 16 tons apiece.

Each of the four propelling machinery units can be operated independently and consist of four turbines, high-pressure, first intermediate pressure, second intermediate pressure and low-pressure turbine and con

denser. Also, there are four sets of single reduction gears. Steam is at 440 lb. per sq.in. working pressure, and a total temperature of 700 deg. The turbine is rotated at 5,000 r.p.m., which is reduced to 500 r.p.m. for the generators.

A.S.T.M. Committees Hold Group Meetings

A TOTAL of about 140 meetings of main committees, sections and sub-committees of the A.S.T.M. were held in Pittsburgh at the Hotel William Penn during the week of March 2 to 6. Following the usual procedure, the actions taken by the committees relative to standardization will be submitted to letter ballots of the various committees prior to formal recommendations to the society at the annual meeting in June. In addition to the discussion of standardization problems, numerous research programs were reviewed.

The joint committee on electro-plating coatings, sponsored jointly by the American Electro-Platers Society, National Bureau of Standards and the American Society for Testing Materials, discussed the reliability of salt spray tests for electro deposited coatings of zinc, cadmium, nickel and chromium on steel. The discussions indicated that the salt spray test is not especially useful for testing zinc and cadmium coatings.

It was the sense of the meeting that while the present symbols and present specifications are satisfactory, consideration could be given also to a designation based on the specified thickness of the electro-deposited coating. For example, "Zinc 50" would refer to a zinc coating with a minimum thickness of 0.00050 in. minimum thickness. Consideration of the present requirement calling for an average of 0.00002 in. of chromium, indicated that this is not excessive for the automotive industry, and the committee recommends that the specifications be continued as tentative standards for another year without change.

The committee on die-cast metals and alloys plans to include in its 1936 report a paper covering details of methods for finishing zinc and aluminum-base alloy die-castings. Two types of electro-plating of zinc die-castings will be described and the preparation of casting surfaces and methods for application of lacquer, enamel, japan, etc., with data for other miscellaneous finishes applied to zinc die-castings, are to be included.

The committee on light metals and alloys has prepared a new specification for magnesium-base alloy bars, rods and shapes, which it is planned to submit for approval as a tentative standard. These specifications allow more stringent requirements on impurities and will also provide for the introduction in the specifications for magnesium-base alloys and castings of properties for Alloy No. 4 in the heat-treated condition. It appears that this alloy will be the most widely used composition of this type. It is reported to have excellent corrosion-resisting properties.

MEETINGS

Refrigerating Machinery Association—Hot Springs, Va., May 14-16. William B. Henderson, secretary, 915 Southern Bldg., Washington, D. C.

Scientific Apparatus Makers of America—Annual meeting, Edgewater Beach Hotel, Chicago, Ill., June 1-3. J. M. Roberts, secretary, 20 N. Wacker Drive, Chicago, Ill.

American Society of Mechanical Engineers — Semi-annual meeting, Dallas, Texas, June 15-20. C. E. Davies, secretary, 29 West 39th St., New York, N. Y.

American Society of Refrigerating Engineers—Skytop Lodge, Skytop, Pa., June 22-24. David L. Fiske, secretary, 37 West 39th St., New York, N. Y.

American Society for Testing Materials—Annual meeting, Atlantic City, N. J., June 29-July 3. R. E. Hess, assistant secretary, 260 S. Broad St., Philadelphia, Pa.

EXHIBITIONS

American Foundrymen's Association—Annual meeting and exposition, Detroit, Mich., May 4-9. C. E. Hoyt, secretary, 222 West Adams St., Chicago, Ill.

Courses in Pressed Metal Design

BECAUSE of the lack of opportunities for receiving training in pressed metal engineering and die design, the University of Toledo inaugurated a new evening course in that subject. E. V. Crane of the engineering staffs of the Toledo Machine & Tool Company and the E. W. Bliss Company is giving the course which includes lectures, mutual discussions, the working out of problems, lantern slide talks and laboratory experiments.

In commenting upon the desirability and necessities of the course which was developed at the request of Professor Zarobski of the mechanical engineering department of Toledo University, Mr. Evans states:

"The cold forming of metal in power presses unquestionably is one of the most important production methods in this country at the present time. At the same time, from an engineering standpoint it is one of the most backward of our major industries, particularly in view of the large amount of information required for successful tool designing and tool operation. The course at the University of Toledo was created in order to meet this situation."

New presses, methods and tools will be discussed, along with a systematic study of dies for different classes of operations. Other subjects include required press pressures, how metals behave internally and why, differences between metals, die design, die setting, special press equipment, unusual types of press operation, and hot and cold forging.

It is interesting to note that the University of Michigan, University of Illinois, Johns Hopkins University and Case School of Applied Science have already started some work toward the establishment of similar courses on the above subjects.

Do You Know That—

- The average service life of rubber goods has been doubled since the World War. (10)

- A stainless steel plate, 70 in. wide and 208 in. long has been successfully machine polished to a No. 4 grade. In area, it is the largest plate of stainless steel ever rolled and polished. (11)

- Reflectors for lighting fixtures are now molded in plastics. Advantages include, no glare, only 18 per cent light absorption, half the weight of comparable metal and glass fixtures, and more than 7,000 colors from which to choose. (12)

- The exceptional tone quality of a solid platinum flute costing $3,000 is attributed to the high density of the material which is heavier than gold. (13)

- One company has found that because of its high strength and wear resistance, iron containing 2.75 per cent total carbon, 1.30 per cent nickel, and 0.50 per cent molybdenum is suitable for mowing machine gears. (14)

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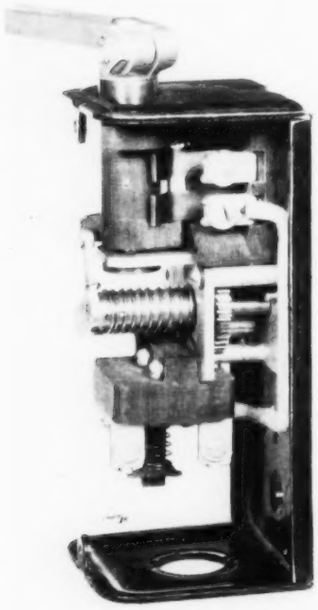
New Materials and Parts

Shipper-Rod-Operated Switch



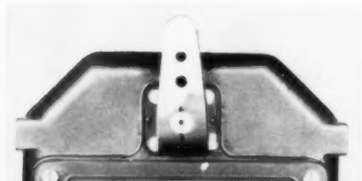
Master switch operated by shipper-rod performs the function of a two-button momentary-contact pushbutton station. Magnetic contactor will "pick-up" and "seal-in" even though the shipper-rod is operated rapidly. Contactor will drop out and remain unenergized in case of voltage failure if the shipper rod does not complete its travel. A short time delay between making and breaking the pick-up circuit is employed, so the circuit will always be broken after once established, regardless of position in which shipper-rod is left. General Electric Co., Schenectady, N. Y.

Welding Bronze, Brass and Copper

A phosphor bronze arc welding electrode, called "Aerisweld" is used for welding bronze, brass and copper. The electrode is said to provide a solid homogeneous deposit, having characteristics of true phosphor bronze with high tensile strength. By the use of this electrode, busbars, large contacts, impeller blades in pumps and turbines, ornamental bronze, bronze doors and other pieces which are usually difficult to braze are said to be readily welded. It is said that the electrode can also be used for welding galvanized sheets where minimum disturbance of the galvanizing is essential. It can also be used for welding bronze bearing surfaces on steel or cast iron. Pre-heating of parts is unnecessary when welding any ferrous metal and the lighter grades of copper and bronze. Heavy sections are usually preheated before welding. The Lincoln Electric Co., Cleveland, Ohio.

Motor Operated Valves Controller

Two types of multi-position controllers known as the "Relatrol" and the "Balancer" for producing a corrective



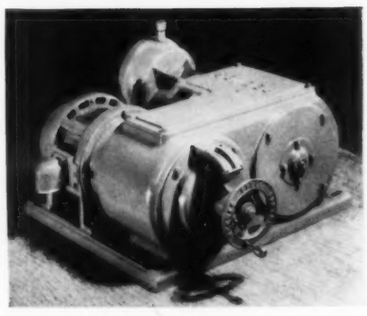
movement in a valve or dampner in exact relation to departure from the temperature setting as measured by the actuating instrument. Both units are alike externally. For the Relatrol, a special relay is supplied, wired into the circuit between the actuating instrument and the motor mechanism. This relay embodies an electrically controlled null-point, and as full line voltage is used in both relay and power motor, extra responsiveness is said to be secured. By slightly modifying the contact mechanism, the Relatrol can be used in conjunction with standard pyrometers, flow-meters and other measuring instruments. A hand operated index and dial replaces the actuating instrument for manual remote control.

The Balancer is similar to the Relatrol except that it is provided with automatic means of load compensation and is recommended where load changes will be of considerable extent and duration. The mechanism is housed in a cast-iron case to withstand rough usage of industrial service. Automatic Temperature Control Co., Inc., 34 E. Logan St., Philadelphia, Pa.

Vari-Speed Motodrive

A variable-speed drive which combines in a self-contained inclosure any standard make of constant speed motor, a variable speed control mechanism and, where required, speed reduction gears. Any make of foot type, constant speed motor, with standard N.E.M.A. dimensions, may be used. By turning a hand-wheel any desired speed within the range of predetermined limits is smoothly and quickly available. A dial indicator registers speed on a scale calibrated from 1 to 6. This variable speed drive operates on the principal of a V-belt running between two sets of cone-faced disks which are adjustable in diameter, and mounted on parallel shafts. One shaft receives power at constant speed from the motor, and the other shaft transmits power at infinitely adjustable speeds to the driven machine. Ventilation of motor and variable speed mechanism is provided. The variable speed shaft may be extended on either side of the unit as required.

Both horizontal and vertical drives



are available and are built in four sizes accommodating motors of ¼ to 7½ hp. capacities having speed ratios of from 2 to 1, to 6 to 1. Reduction units of helical gear type in ratios up to and including 189 to 1 may be incorporated

in the drive. In different combinations of sizes, ratios and reduction gears, output speeds ranging from 1.35 r.p.m. to 3,480 r.p.m. may be obtained. Within certain limitations, the units may be mounted on walls, floor or ceiling, or directly on the driven machine. Reeves Pulley Co., Columbus, Ind.

Mercury-Vapor Lamp

This high-intensity mercury-vapor lamp has a tubular bulb with a standard screw base socket. Is used in either commercial or industrial applications, which do not permit use of a standard 400-watt mercury-vapor lamp. Rated at 250 watts, it is said to have an efficiency of 25-30 lumens per watt. It is of the universal burning type, functioning efficiently in the vertical, horizontal or angular positions and is claimed to have an operating life of 2,000 hr. It is also claimed to have as much light as is delivered by 425 watt in incandescent lamps. The lamp has a maximum overall length of 8 in., and a bulb diameter of $1\frac{1}{8}$ in., and is available in clear finish. A number of newly designed reflectors of the single and combination types, specifically designed for this lamp are now obtainable. A special individual transformer or reactor is required for the proper operation of each mercury-vapor lamp. General Electric Vapor Lamp Co., Hoboken, N. J., and the Incandescent Lamp Department, Nela Park, Cleveland, Ohio.

Dial Thermometers

Type 61 and 62 are of the self-contained, distant reading type. Type 61 is fitted with a universal socket which permits the use of the instrument as a vertical connection, a 90 deg. back angle, and a front angle thermometer or at any intermediate angle. Type 62, also of the distant reading type is supplied with a 6 ft. connecting tubing and a union bulb. For high temperatures, either a union bulb or a flexible plain bulb is supplied. This thermometer has a mounting flange with a universal socket for wall or pillar mounting. Various Fahrenheit scale ranges are available from —20 deg. up to 800 deg. Corresponding centigrade scales are also available. The graduation arc on the dial of

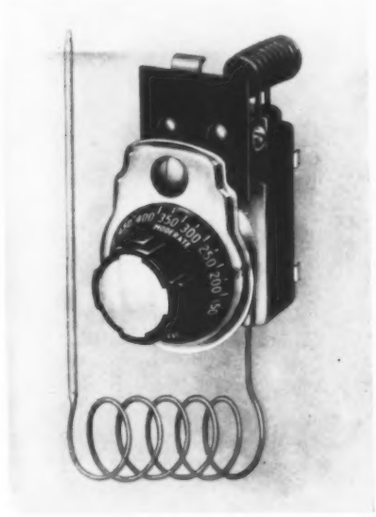
these instruments is approximately 9 in. long. The dials are $3\frac{1}{2}$ in. diameter and are available in a number of finishes. Jas. P. Marsh Corp., 2073 Southport Ave., Chicago, Ill.

Speed Recorder

This "Micromax" speed recorder can be placed remotely from the rotating member. The speed can be continuously indicated and recorded at any desired location regardless of the distance between the two members. A heavy-duty tachometer magneto, attached to the rotating shaft, generates an electromotive force proportional to the speed which is carried by ordinary lead wires to the recorder. The speed is immediately indicated on a moving chart. The recorder can also be equipped for actuating signals or any type of warning device if so desired. This equipment is used to register the speed of rayon, silk and paper machines, mixers, and dryers, turbines, cement kilns, presses and other moving mechanism. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

Hydraulic Thermostat

Is used for domestic or commercial heating equipment where remote control of temperature is desired. Can be applied for air or liquid temperatures as in electric ovens, dryers, incubators, water-heaters, glue pots and other applications. The control knob with temperature readings can be placed at a convenient exterior location. A low-voltage pilot with red indicating bullseye to indicate when desired temperatures are obtained can be supplied. The Hart Mfg. Co., Hartford, Conn.



Dielectric Tester

Is used as a breakdown tester, not only for indicating shorts, opens, or grounds, but also for checking circuits at approved standard testing voltages. It is stated that the tester will permit actual applications of the standard testing voltage of double the rating voltage, plus 1,000 to the appliance device or equipment under test and thus prove the dielectric strength of the insulation to meet standard safety limits. Any windings with rotted, old or defective insulation, below minimum safety standards would break down under test, necessitating proper rewinding or repairing and thus pre-

venting the usage of unsafe electrical equipment.

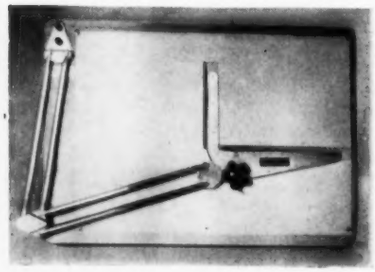
The tester can be plugged into a 110 volt, 60 cycle outlet. Secondary connections are supplied with high voltage cable leads each equipped with a test prong. The secondary test voltage is manually controlled by a tap-switch that provides any voltage from 500 to 2,500 volts. The 100 per cent leakage type transformer used in this device permits short circuit for a period of time without any damage. This current limitation is also said to eliminate burning of materials at point of breakdown of the apparatus under test. A red lamp glows when the tester is turned on. The Acme Electric & Mfg. Co., Cleveland, Ohio.

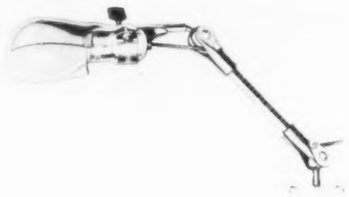
Synthetic Enamel

Roxyn 12 B high gloss baking enamel is said to be resistant to cigarette burns and alcohol without discoloration or softening. It is claimed that a coaster immersed in straight alcohol for one hr. did not injure the finish. Can be applied by spraying or dipping and baked for one hr. at 300 deg. F. Bright reds and greens which would ordinarily discolor are available in the new material. Roxalin Flexible Lacquer Co., Elizabeth, N. J.

Drafting Machine

The Wrigraph Model E-272 drafting machine is newly designed and is mounted on a 22 by 30-in. cleated white pine board. The parallel mechanism is made of all steel nickel-plated parts and has solid phosphor bronze bearings. The vernier indicating protractor reads in degrees. The graduated L-square blade is made of pyroxylin and riveted to a light-weight aluminum stiffener, satin-finished to eliminate glare. The drawing edges of the blades are transparent. The boards accommodate drawings up to 20 in. by 26 in. The machine may be obtained with a special base plate to fasten to any flat wood surface. L. G. Wright, Inc., 5713-9 Euclid Ave., Cleveland, Ohio.





Machine Lamp

Primarily designed for industrial sewing machines, No. 16 lamp can be used on any machine where localized lighting is required. Ball and socket joints provide the necessary flexibility with sufficient rigidity to withstand shocks and vibration. The reflector is said to give a direct, glareless light with either 15 or 25-watt bulbs. The base is drilled with ¼-in. holes. Furnished in black and green, although the equipment is available in any desired color, including chromium. Industrial Lamp Division of the Fostoria Pressed Steel Corp., Fostoria, Ohio.

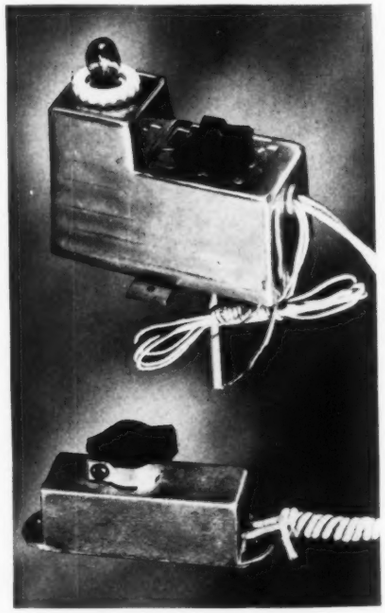
Motor with Back-Gear Reduction

Fractional horsepower motor with gear reduction of 1/45 to 1/30 hp. capacity. Motor is a.c. 4-pole of induction shaded coil construction for long hour service. The copper shade for starting eliminates the usual centrifugal switch, condenser or brush and commutator. Said to have high starting torque. Gear reduction 1.6 r.p.m. to 150 r.p.m. available. Can be furnished in 4-pole, series wound (brush type) for d.c. operation. Runs on 110 volts. Signal Electric Mfg. Co., Menominee, Mich.

Pencil and Strip Thermostats

The thermal element of the pencil thermostat (upper) comprises an invar rod fastened to a brass tube which actuates a contact lever during change of temperature. A neon pilot light is mounted on the aluminum case. An external capacitor is supplied for connection to the contactor. Housing is 4¼ in. long, 2¼ in. wide and 2⅞ in. high. The standard thermal element is ⅜ in. diameter and 8 in. long but can be varied for special requirements. Has ratings of 2,000 watts a.c. and 900 watts d.c., both at 110 or 220 volts. Has a temperature range up to 500 deg. F. and a temperature differential of 1 deg. F. Can be used for immersion in liquids for ovens, molding, presses and other applications.

The Strip Thermostat (lower) has a bimetal and steel spring mounted in a cast aluminum case. Normally closed contacts of electrolytic silver are standard but normally open contacts



can be supplied special. The thermostat has a rating of 1,000 watts at 110 or 220 volts a.c. For d.c. a condenser should be connected across terminals. Has a temperature range up to 550 deg. F. and a temperature differential of 5 deg. F. Is 4¼ in. long, 1¼ in. wide and 1¾ in. high. Can be mounted on flat surfaces and is used for heating plates or tanks. With perforated housing the thermostat is suitable for ovens. George Ulanet Co., 85 Columbia St., Newark, N. J.

Lamp for Home Appliances

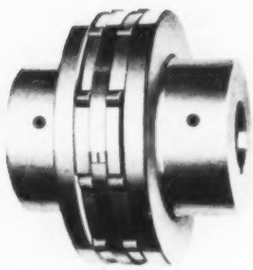
Mazda lamps of separate design for sewing machines and vacuum cleaners have been superseded by a single design for all kinds of service in home appliances. In the past sewing machine lamps were designed to withstand vibration, while vacuum cleaner lamps not only withstood vibration, but severe shocks incidental to vacuum cleaner usage, as well. The new home appliance lamp is identical in design and construction to the former vacuum cleaner lamp. Lamps rated at 15 and 20 watt of 30-34 and 110-115-120 volts are available in a number of bases. The maximum overall length is $2\frac{5}{8}$ in. They may be had either clear or frosted. Westinghouse Lamp Co., Bloomfield, N. J.

Selfvulc Bonding Solution

This M bonding solution is used for applying a rubber lining or coating known as Selfvulc, to surfaces of glass, metal, wood, concrete or brick. The coating is a self-cold-curing plastic rubber compound and comes in paste form. It is applied with a spatula. Selfvulc can be used as a protective coating for chutes, hoppers, centrifugal pumps, tubs, agitators, impellers, hose, tubes and cables. Self-Vulcanizing Rubber Co., Inc., 605 West Washington Blvd., Chicago, Ill.

Flexible Coupling

Type W is used for heavy duty and is of the non-lubricated type. Individual load cushions are free floating between the metal jaws and are secured by a spiral steel spring. Cushions are said to be free to move and adjust themselves instantly to any momentary position of the jaws. There is no metal to metal contact. Three types of resilient cushioning materials are available—brake-lining, leather or rubber duck fabric. Made



in standard sizes with bores from 3 to 14 in. diameter and for 18 to 2,000 hp. at 100 r.p.m. By application of suitable materials, capacities can be increased without change of overall dimensions. Lovejoy Tool Works, 5019 West Lake St., Chicago, Ill.

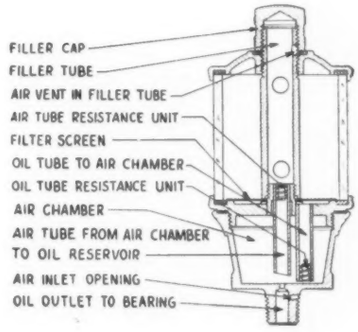
Pumping Unit

This type U pumping unit is used for domestic oil burners and incorporates a strainer, a pressure regulating and cut-off valve and a pumping unit of 18 or 26 gal. per hr. capacity. The valve and strainer section is detachable from the pump. Ports are

provided for pressure and vacuum gages. The valve can be placed on either side as the pump is furnished to drive in either direction of rotation. Can be used for pressures up to 250 lb. Four standard types of mounting brackets are available. Viking Pump Co., Cedar Falls, Iowa.

Thermatic Oil Cup

Is used where a constant, slow flow of oil is desired. It requires no attention other than filling, as it operates



by expansion of air caused by the normal increase in temperature in a running shaft bearing. It is said that a rise in temperature of 1.8 deg. F. causes the oil to flow. Change of room temperature is also said to start the oil to flow, thereby keeping the bearings of idle machinery lubricated. Oil is strained by an 80-mesh filter screen. There are no moving parts. The cup is chrome-plated. Alemite Division of Stewart-Warner Corp., 1826-52 Diversey Parkway, Chicago, Ill.

MANUFACTURERS' PUBLICATIONS

The A-B-C of Silent Chain Drives—Ramsey Chain Co., Inc., Albany, N. Y. Booklet, 19 pages, $3\frac{1}{2}$x$6\frac{1}{4}$ in. A concise review of the construction of silent chains, how they operate, what they will do and information on lubrication and care. Both line drawings and photographs are used to illustrate the features of this type of chain.

Handbook on Worm Gearing and Worm Gear Speed Reducers — Foote Bros. Gear & Machine Co., 5301 So. Western Ave., Chicago, Ill. Catalog No. 350, 86 pages, $5\frac{1}{4}$x$7\frac{3}{4}$ in. In this handbook of pocket size, the first 19 pages contain the history of worm gear evolution and "the customer's problem." The latter contains information on materials and design of worm gear reducers. General engineering data are also included in this section. There are numerous photographs of reducer applications for various industries. Engineering data for the selection of worm gear reducers are given in another section including ratios and input ratings. Dimensioned outline drawings are given for the various types of reducers made.

Debecote—The Debevoise Co., 968-978 Grand St., Brooklyn, N. Y. Booklet. "Erosion—Its Prevention and Cure Through the Use of Debecote"—12 pages, 6x9 in. A report of a protective coating for the prevention of erosion for both ferrous and non-ferrous metals that are exposed to water in motion, particularly if the water contains free or entrained air.

Seamless Flexible Metal Tubing — American Metal Hose Branch of The American Brass Co., Waterbury, Conn. Bulletin 1936-1, 15 pages, $8\frac{1}{2}$x11 in. Explains the essentials of construction

and shows typical installations. Tubing of aluminum, steel, monel and other metals is available for chemical service where bronze cannot be used. Various types of "bracketubes" are illustrated, a patented bracket attachment for holding the tubing in a horizontal position at all times. A descripion of the different types of hoses and couplings is included.

Improved Fabrication of 18-8 Chromium Steels — The Linde Air Products Co., 205 E. 42nd St., New York, N. Y. Booklet, 8 pages, 8½x11 in. Illustrated discussion of improvements in welding technique and materials. Outstanding properties of 18-8 chromium steels are reviewed to point out the need for improved fabrication. Booklet is intended for those interested in the welding of chromium steels. A section on simplifying fabrication problems is included.

Industrial Instruments — Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh, Pa. Catalog, 31 pages, 8½x11 in. Pressure indicators for diesel, gas and steam engines, also for high speed engines are illustrated and described in detail. Differential pressure and wide-range pressure indicators are also included.

Useful Facts About Armco H.T.-50. —The American Rolling Mill Co., Middletown, Ohio. Folder, 4 pages, 8½x11 in. Describes a special high tensile steel that absorbs 5,000 ft.lb. per sq.in. in tensile impact test, and elongate 33 per cent in 2 in. Has an endurance limit of 48,000 lb. per sq.in. as determined by the rotating beam test. Plates, hot rolled annealed sheets and strip, and cold rolled sheets and strip are available.

Vacu-Break Safety Switch—Bulldog Electric Products Co., Jos. Campau Ave., Detroit, Mich. Bulletin, 16 pages, 8½x10 in. Describing the construction features of a new principle as applied to electric switches in which the conventional procedure is reversed, the arc-extinguishing structure being placed on the moving contact instead of on the stationary contacts.

BOOKS AND BULLETINS

Modern Uses of Non-Ferrous Metals

A. I. M. E. Series. 427 pages, 5 x 8 in. 32 illustration, 14 tables. Red clothboard covers. Published by American Institute of Mining and Metallurgical Engineers, 29 West 39th St., New York, N. Y. Price $3.

The 21 chapters of this first edition have been written by as many contributors, each a recognized specialist in his field. The book is a survey of the common metals and many minor metals which are comparatively unknown and used as alloying elements. It is written in a narrative style in non-technical language. In the first chapter, Exploitation of Metals and Alloys, the author divides industrial non-ferrous metals into two general classes: (1) those used in substantial quantities in the pure state or serving as the base metal for alloys, covering 16 metals from aluminum to zinc. (2) The second class contains 19 metals that are used essentially as alloying constitutents ranging from antimony to zirconium. The non-metallic or semi-metallic elements are also listed.

Each chapter is complete in itself. Twenty-five pages are devoted to aluminum. Arsenic, antimony and bismuth are covered in two chapters. Chromium has 30 pages, likewise copper. Cobalt, lead, gold magnesium and molybdenum are discussed in separate chapters. Forty-one pages are devoted to nickel. Miscellaneous alloy-forming elements include beryllium, calcium, cerium, lithium, manganese, titanium, vanadium and zirconium. In other chapters, platinum, quicksilver, selenium and telurium, silver, tantalum and columbium and tin are discussed. A chapter on zinc and cadmium complete the book.

Graphic Solutions

Charles O. Mackey. 127 pages, 6 x 9 in. 52 illustrations. Gray clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $2.50.

This book of graphical or mechanical representation of equations is the outgrowth of a course at Cornell University. However, it is not a treatise on graphical computations as no attempt has been made to abstract anything previously written. The treatment is elementary, and with but few exceptions most of the examples can be handled with a working knowledge of logarithms, algebra and a few principles of plane geometry.

The five chapters of the book relate to stationary adjacent scales, sliding scales, network or intersection charts, alignment charts, empirical equations and non-periodic curves. In the chapter of sliding scales is shown the construction and calculations for special slide rules for as many as six variables. In the section relating to network or intersection charts, graphical representation is shown of equations containing three or more variables. Under alignment charts are discussed the various types such as parallel line charts, Z-charts, charts with parallel or perpendicular solution lines, and those having curved scales. In the last chapter of empirical equations is shown how the results of experiments may be plotted on rectangular coordinates. A separate chart of 10 logarithmic scales is included.

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Psychrometric Chart

General Electric Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N. J. Chart, 14x20½ in. Non-inflammable material. Price $3.

This chart is used for solving problems encountered in calculating the properties of air for air conditioning. The arrangement of lines on the chart is designed for greater accuracy of problem solutions and to save time. Values of all characteristics can be read without the use of auxiliary curves from any stated point on the chart. The chart is made of a laminated resinous substance with paper sheets, imprinted with charts and explanatory data, and sealed to both sides. The exposed surfaces are coated with a layer of synthetic resin. This finish gives a surface upon which pencil lines can be made. These marks can be erased or washed off without affecting the chart data. Chart is printed in black and brown.

Tin Research

Six recent reports, listed below, are published by the International Tin Research and Development Council. Copies are available free from L. J. Tavener, 149 Broadway, New York, N. Y.

"Tin and Its Uses," No. 4, 16 pages.

"Striations in Tin Coatings on Copper," Series A, No. 23, 7 pages.

"The Mechanical Properties of Tin-Base Alloys," Series A, No. 26, 11 pages.

"The Electrodeposition of Bronze Using Bronze Anodes," Series A, No. 27, 14 pages.

"The Electrodeposition of Bronze Using Bi-Metallic Anodes," Series A, No. 28, 8 pages.

"Research of Thin Layers of Tin on Other Metals. (1) The Influence of Thin Metal Layers on the Deterioration of Technical Insulating Oils," Series A, No. 29, 7 pages.

Agathon Alloy Steels

Republic Steel Corp., Massillon, Ohio. Data book, 105 pages, 6x9 in. Flexible clothboard covers.

A clear and concise text on alloy steels showing the "whys and wherefores" of the addition of nickel, chromium, vanadium, molybdenum, copper or silicon to steel. A chapter on the selection and heat-treating of alloy steels contains information on the critical ranges of temperature, heating and quenching, and quenching speeds. The McQuaid-Ehn test and its significance is discussed, being accompanied by grain size chart photographs. Thirteen S.A.E. oil and water hardening steels, eight carburizing steels and six "Uma" steels are included in several chapters. Each type is accompanied by physical property charts with explanation of their use. Other sections of the book contain steel data relative to the use in various industries such as the railroad, oil and other industries. A number of pages of chemical and metallurgical data and testing definitions are included.